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Roman Glassblowing in a Cultural Context

E. MARIANNE STERN

Abstract

Commercial glassblowing dates from the beginning of Augustus' rule. This paper focuses on the impact of this novel technique on Roman society: the development of the technique, the artisans who made the glass, the merchants who marketed it, and the customers who bought and used glass vessels. The perfection of glassblowing is characterized by improvements in tools and equipment and the discovery that molten glass can be blown, a discovery that was closely connected with recycling. The division into two separate branches—one for making raw glass from primary ingredients, the other for working the material and creating glass objects—determined the structure of the industry. Gender, names, and business relationships between glassblowers are explored. Diocletian's Price Edict (PE) provides important clues to start-up business expenses. Dominated by the division into two branches, glass commerce and trade were brisk, both within and beyond the borders of the empire. Glass vessels played a significant role in the daily life of all segments of society. The forms and function of glass vessels in the West and in the East are discussed separately.*

WONDROUS GLASS

Petronius relates the following story about glass: "There was a craftsman once who made a glass bowl that didn't break. So he got an audience with the emperor, taking his present with him. Then he made

* I wish to thank the anonymous readers of *AJA* for saving me from an embarrassing oversight as well as for many useful comments and suggestions. J. Reynolds (Cambridge) commented on my new suggestions for PE 16. 7–9. My research benefited greatly from discussions with Heimo Dolenz (Magdalensberg), Andrea Rottloff (Augsburg), Lucia Saguì (Rome), Mara Sternini (Rome), and Luigi and Luisa Taborelli (Torino). T. Gagos and P. Heilporn (Ann Arbor) assisted with locating papyrological sources. S.E. Knudsen (Toledo), E. Roffia (Milan), and A. Rottloff provided information on vessels in their care and donated photos for use. Additional thanks for photographs goes to Lee Mooney (Toledo); Soprintendenza Archeologica (Milan); and the Ernesto Wolf Collection (Stuttgart and Paris). I am very grateful to many unnamed colleagues who provided me with publications of their own and others. Finally, my thanks for many years of friendship go to Gladys D. Weinberg, to whom this article is dedicated.

All dates are A.D. unless otherwise noted. All references to pounds refer to Fustat or Roman pounds. Literature citations in notes are arranged in chronological order of publication.

The following abbreviations are used:

AnnAIHV	Vols. 1–9 published in Liège: vols. 1–3: *Annales du 1er/2e/3e congrès des Journées internationales du Verre*; vol. 4: *Annales du 4e Congrès International d'Etude Historique du Verre*, vol. 5 ff: *Annales du . . . Congrès de l'Association Internationale pour l'Histoire du Verre*; vols. 10–12 publ. in Amsterdam; vols. 13– publ. in Lochem, Netherlands.
Cool and Price	H.E.M. Cool and J. Price, *Roman Vessel Glass from Excavations in Colchester 1971–85* (Colchester Archaeological Report 8, Colchester 1995).
DeLaine	J. DeLaine, *The Baths of Caracalla. A Study in the Design, Construction, and Economics of Large-Scale Building Projects in Imperial Rome* (*JRA* Suppl. 25, Portsmouth 1997).
Giacchero	M. Giacchero, *Edictum Diocletiani et Collegarum de pretiis rerum venalium* (Genoa 1974).
Goitein	S.D. Goitein, *A Mediterranean Society* 1: *Economic Foundations* (Berkeley 1967).
Isings	C. Isings, *Roman Glass from Dated Finds* (Archaeologica Traiectina 9, Groningen 1957).
van Lith and Randsborg	S.M.E. van Lith and K. Randsborg, "Roman Glass in the West: A Social Study," *Berichten van de Rijksdienst voor het Oudheidkundig Bodemonderzoek* 35 (1985) 413–32.
PE	Diocletian's PE, quoted after Giacchero unless otherwise noted.
Rütti	B. Rütti, *Die römischen Gläser aus Augst und Kaiseraugst* (Forschungen in Augst 13, Augst 1991).
Stern 1994	E.M. Stern and B. Schlick-Nolte, *Early Glass of the Ancient World 1600 B.C.–A.D. 50: Ernesto Wolf Collection* (Ostfildern-Ruit 1994).
Stern 1995	E.M. Stern, *Roman Mold-blown Glass: The Toledo Museum of Art* (Rome 1995).
Stern (in prep.)	E.M. Stern, *Roman, Byzantine and Early Medieval Glass: Ernesto Wolf Collection* (in prep.).
Two Centuries	M. Newby and K. Painter eds., *Roman Glass: Two Centuries of Art and Invention* (The Society of Antiquaries of London, Occasional Paper 13, London 1991).
Weinberg	G.D. Weinberg ed., *Excavations at Jalame: Site of a Glass Factory in Late Roman Palestine* (Columbia 1988).

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Caesar hand it back to him and dropped it on the floor. The emperor couldn't have been more shaken. The man picked the bowl off the ground—it had been dented like a bronze dish—took a hammer from his pocket and easily got the bowl as good as new."[1]

Vitrum[2] was the most versatile material known to the Romans. Pliny (*HN* 36.195) calls it *vitrum flexile* "flexible/malleable glass." Like modern plastics, glass mimicked other materials in shape, color, and design: *neque est alia nunc sequacior materia* "there is no other material nowadays that is more pliable" (Plin. *HN* 36.198). When glass is soft, it can be stretched and expanded or made to compress. The almost miraculous fluidity of the material when it is hot, and the unlimited possibilities of transforming its shape on the blowpipe from tube to sphere to square and back again to cylindrical, as well as stretching, widening, and pinching the opening of the mouth once the glass is separated from the pipe, are a never ending source of fascination for glassblower and spectator alike. During blowing, glass seems to defy the laws of nature. Even if a piece falls off the blowpipe or punty, it will not shatter! If the blower reattaches it quickly and reheats, he or she can restore the shape and complete the piece as planned.

Such a workshop accident might be at the root of Petronius' story about an unbreakable glass cup that was dropped to the floor, got dented like a metal vase, and was hammered back into shape. The story is told by several ancient authors, sometimes with the comment that the glass had been tempered (*temperamentum*) to make it malleable or flexible (Plin. *HN* 36.195; Origenes 16.16.6).[3] In spite of Pliny's dismissal of the story as a fantasy, the suggestion that the Romans actually invented unbreakable glass continues to intrigue chemists and physicists.[4] It is not difficult to imagine how an eyewitness account of a workshop incident, as described above, could have been embellished with physically impossible details such as the glassblower pulling a little hammer out of his pocket and hammering out the dent in front of the emperor. After all, Pliny himself was of the opinion that glass could be hammered into relief like silver: *argenti modo caelare*, "(some glass is) chased like silver" (*HN* 36.193). This misconception reappears in Martial (*Epigr.* 14.94): *audacis plebeia* toreumata *vitri* "plebeian *chased* cups of dreadnought glass" (author's emphasis). In reality, glass vessels decorated with relief were produced by the technique known as mold-blowing.[5]

ROMAN GLASSBLOWING: THE PERFECTION OF A CRAFT

The discovery that glass can be expanded and shaped by human breath revolutionized glassworking to such an extent that today "glassblowing" has become the generic term for all glassworking, whether the glass is blown or formed by other techniques. The invention of the blowpipe meant that hollow objects and vessels that previously required labor intensive operations[6] could now be made much more quickly and that less glass per object was necessary. Moreover, blowing permitted the production of new classes of items.[7]

The beginning of commercial glassblowing coincides roughly with the creation of the Roman empire. Within half a century the art of glassblowing was transformed from a local Syro-Palestinian craft to an empire-wide enterprise. Around the mid-first century glassblowing facilities began to spring up throughout the empire and beyond. Important first-century

[1] *Fuit tamen faber qui fecit phialam vitream quae non frangebatur. Admissus ergo Caesarem est cum suo munere, deinde fecit reporrigere Caesarem et illam in pavimentum proiecit. Caesar non pote validius quam expavit. At ille sustulit phialam de terra. Collisa erat tamquam vasum aeneum. Deinde martiolum de sinu protulit et phialam otio belle correxit* (*Sat.* 51; all translations of this work are those by J.P. Sullivan, *The Satyricon, and the Fragments* (New York 1965). All other translations, unless otherwise noted, are taken from Loeb Classical editions.

[2] The etymology of *vitrum* has given rise to many conjectures, but linguists agree that the origin of the word is not Latin. E.R. Knauer, "III Glass and Pigment," *MMAJ* 28 (1993) 28–34 suggests that *vitrum* is of Celtic derivation, perhaps from a root *uei* "bend, twist" (cf. English *wire*) as preserved in the Celtic word *viriolae* (Celtiberic *viriae*).

[3] M.L. Trowbridge, *Philological Studies in Ancient Glass* (University of Illinois Studies in Language and Literature 13, 1930) 110–12.

[4] R.C.A. Rottländer, "Naturwissenschaftliche Untersuchungen zum römischen Glas in Köln," *KölnJb* 23 (1990) 563–82; G. Eggert, "*Vitrum flexile* als Rheinischer Bodenfund," *KölnJb* 24 (1991) 287–96.

[5] Stern 1995, 68.

[6] On alternative techniques for shaping glass vessels: Stern 1994 (with lit.); R. Lierke, *Antike Glastöpferei* (Sonderheft *AntW*, Mainz am Rhein 1999).

[7] Useful general introductions to Roman glass are given by D.B. Harden, "Ancient Glass, II: Roman," *AJ* 126 (1969) 44–77; J. Price, "Glass," in D. Strong and D. Brown, *Roman Crafts* (London 1976) 111–25; Price, "Glass," in M. Henig ed., *A Handbook of Roman Art* (Oxford 1983) 205–19.

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glassblowing sites include Avenches, Lyon, and Saintes, to mention just a few.[8] Several workshops appear to have produced vessel glass and window panes, e.g., at Sentinum (Italy), Aix-en-Provence, Bet She'an, and—perhaps—at Sardis,[9] but at other sites where glass vessels were made there is no indication of the production of flat glass.[10] Glass beads and jewelry were almost always made in workshops that specialized in this particular aspect of glass production.

The earliest glassblowers plied their craft on the Syro-Palestinian coast and in Italy. North Italy, Dalmatia, and the Ticino Valley appear to have been at the forefront of glassblowing, but Campania was probably very active as well.[11] According to Pliny (*HN* 36.193), glassblowing (*flatu figurare*, "shaping by breath") was formerly a specialty of Sidon (modern Saida, in southern Lebanon). The unprecedented speed with which the new technique spread throughout the empire was due to a range of factors: political, economical, and technical. Augustus' rule ended a century of civil strife in Italy and created a vast network of pacified provinces. Speedy communication became possible from one end of the empire to the other. Italy experienced an economic boom that attracted artisans and merchants from all corners of the empire, and especially from the eastern Mediterranean. Most of the areas where glassblowers settled—Rome, Campania, and the northern Adriatic coast—already had longstanding commercial contacts with Greece and the eastern Mediterranean.[12] Finally, glassblowing itself probably did not require a huge investment in expensive new tools because the earliest vessels could all have been blown with inexpensive blowpipes fashioned by the glassblowers themselves.

Whereas the initial discovery that glass can be inflated took place somewhere along the Syro-Palestinian coast,[13] where glassworking and glassmaking boasted a centuries-old tradition, glassblowing was perfected in Italy. The range in quality and quantity of early blown glass excavated in Italy and western Europe far surpasses that from the eastern Mediterranean with regard to variation in shapes, decorative techniques, and function. In Egypt, where the tradition of glassworking began in pharaonic times, artisans were notoriously slow to adopt the new technique of blowing. Alexandria's glass industry, renowned in the Hellenistic period, appears to have suffered a marked decline in the first century. Pliny does not mention Alexandria when he discusses the glass cen-

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[8] J. Morel et al., "Un atelier de verrier du milieu du 1er siècle apr. J.-C. à Avenches," *ArchSchw* 15 (1992) 2–17; H. Amrein (forthcoming); M.-D. Nenna et al., "L'atelier de verrier de Lyon, du 1er siècle après J.-C., et l'origine des verres 'romains'," *Revue d'Archéometrie* 21 (1997) 81–87. Saintes (two sites): A. Hochuli-Gysel, "Römisches Glas aus dem Südwesten von Frankreich," *AnnAIHV* 12, 1991 (Amsterdam 1992) 79–88; B. Velde and A. Hochuli-Gysel, "Correlations between Antimony, Manganese and Iron Content in Gallo-Roman Glass," *AnnAIHV* 13, 1995 (Lochem 1996) 185–91. Glassblowing in Britain began in the early Flavian period: Cool and Price 226. On early glassblowing in Spain: J. Price, "Glass Production in Southern Iberia in the First and Second Centuries A.D.: A Survey of the Evidence," *JGS* 29 (1987) 30–39. For a survey of early Imperial glassblowing facilities, see also D. Foy and G. Sennequier eds., *Ateliers de Verriers de l'antiquité à la période pré-industrielle, Association Française pour l'Archéologie du Verre, Actes des 4e Rencontres, Rouen 24–25 Novembre 1989* (Rouen 1991); Stern 1995, 22.

[9] L.Taborelli, "Elementi per l'individuazione di una officina vetraria e della sua produzione a Sentinum," *ArchCl* 32 (1980) 138–66 (workshop dated mid-first century); L. Rivet, "Un quartier artisanal d'époque romaine à Aix-en-Provence," *RANarb* 25 (1992) 325–96 (workshop dated mid-second to early third century); Y. Gorin-Rosen, "Glass Workshop," in G. Mazor and R. Bar-Nathan, "The Bet She'an Excavation Project 1992–1994," in *Excavations and Surveys in Israel* 17 (1998) 27–29, esp. 29; A. von Saldern, *Ancient and Byzantine Glass from Sardis* (*SardisMon* 6, Cambridge, 1980) 91, 92. No workshop has been identified at Sardis, although cullet and wasters show that glassworkers were active in the city. The similarity in fabric of vessels and window panes suggested to von Saldern that both were made in the same workshops, but it is also possible that different workshops used raw glass made in one factory.

[10] Morel et al. (supra n. 8) (Avenches); Weinberg (Jalame).

[11] Archaeological evidence for glassblowing: Campania: E.M. Stern, "A Small Glass Bottle on Three Pinched Feet," in *Festoen Opgedragen aan A.N. Zadoks-Josephus Jitta bij haar zeventigste verjaardag* (Scripta Archaeologica Groningana 6, Groningen n.d., ca. 1976) 527–38; L.A. Scatozza Höricht, "Syrian Elements among the Glass from Pompei and Herculaneum," in *Two Centuries* 76–85. Ticino: S. Biaggio Simona, *I vetri romani provenienti dalle terre dell' attuale Cantone Ticino* (Locarno 1991); *HelvArch* 22 (1991) 78–143. North Italy: *Vetro e vetri*, exhibition catalogue, Milan, Museo Archeologico, 1 November 1998–18 April 1999 (Milan 1998) 13–146 (glass from recent excavations in Milano and vicinity); M. Calvi, *I vetri romani del Museo di Aquileia* (Aquileia 1968); Calvi, "Arte vetraria Ticinese e arte vetraria Aquileiese: raffronti e analogie," in *HelvArch* 22 (1991) 133–43. Dalmatia: *Trasparenze imperiali Vetri romani dalla Croazia*, exhibition catalogue, Rome, Palazzo Barberini, 1998 (Milano 1997).

[12] L. Taborelli, "Un antico forno vetrario ad Ancona," *Picus* 18 (1998) 219–24, esp. 224.

[13] Y. Israeli, "The Invention of Blowing," in *Two Centuries* 46–55.

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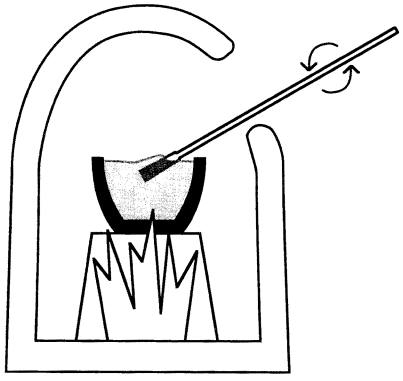

Fig. 1. Modern technique: Gathering hot glass from a pot furnace. (Drawing D.F. Giberson)

ters of his day; nor is the city mentioned by the Flavian poets for whom *crystalla* "crystal glasses" and *calices vitrei* "glass cups" from the Nile were a literary topos. Thebes appears to have been the main exporting glass center of the first century.[14] Political reality may have reinforced Egypt's traditional tendency to look inward for cultural and artistic stimuli.

Attracted by the magnet of good commissions available in Rome, many Sidonian glassblowers migrated to Italy and set up shop in Rome, Campania, and Aquileia. Numerous glass skyphos-handles stamped with the names of Sidonians bear witness to their presence in Rome and other sites in the western Mediterranean. Glassblowers named Ariston, Artas, Philippos, Neikoon, Eirenaios, and their colleagues may be credited with introducing the art of glassblowing to Rome and the West. Epigraphical and archaeological evidence indicates that a *vicus vetrarius* "glassworkers quarter" existed in the vicinity of the Porta Capena at Rome.[15] In Italy the Sidonians came into close contact with the strong utilitarian character of Roman technology. Referring to a period before 7 B.C., Strabo (16.758) noted already that many improvements in the glass industry were taking place in Rome "both with respect to the coloring of glass and to facilitate production techniques, for example for making colorless glass resembling rock crystal" (*krystallophanes*). The interaction and exchange of ideas between Sidonians and Romans furnished the impetus for the innovations and improvements that created the great Roman glass industry.

Fig. 2. Modern technique: Transferring a piece from the blowpipe to the pontil; the blowpipe rests on the arms of the glassblower's bench. (Photo L. Dorfman)

Roman Improvements in Tools and Equipment

Most descriptions of ancient glassblowing are based on the assumption that the craft and its tools are so simple that there was no development in the technique. As recently as 1987, D.B. Harden wrote: "a glassblower blows and finishes a vessel using processes that have never altered, at least in principle, since glassblowing originated."[16] His detailed description of the technique is based exclusively on 20th-century European practice: a gob of molten glass is gathered on an iron blowpipe about 3–5 ft. long (fig. 1) and expanded by blowing; a solid iron rod (also known as a punty or pontil) about 2.5–3.5 ft. long is affixed to the bottom of the vessel with a wad of glass (fig. 2); the vessel is separated from the blowpipe and held on the punty while the mouth of the vessel is finished (fig. 3). He concludes with the remark that the work is usually done with a team of four "with a master-blower in charge, who performs the main blowing and fashioning" seated on a wooden chair (also known as glassblower's bench) with projecting arms on which he balances the blowpipe and pontil (fig. 4). Harden offers no historical or archaeological evidence for any of this description.

No serious discussion of the early development of

[14] E.M. Stern, "Hellenistic Glass from Kush," *AnnAIHV* 8, 1979 (Liège 1981) 35–59, esp. 49.

[15] Stern 1995, 68–69 (Sidonians in Rome). On the *vicus vetrarius*: M. Bacchelli et al., "Nuove scoperte sulla provenienza dei panelli in *opus sectile* vitreo della collezione Gorga," in *Atti del 2 Convegno dell'Associazione Italiana per lo Studio e la Conservazione del Mosaico, Rome, 5–7 December 1994* (Bordighera 1995) 447–66, esp. 455 n. 41.

[16] D.B. Harden, in Harden et al., *Glass of the Caesars*, exhibition catalogue, The Corning Museum of Glass, British Museum, Römisch-Germanisches Museum, Cologne (Milan 1987) 87, since then followed by many scholars.

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Fig. 3. Modern technique: Widening the mouth of the vessel with jacks; the pontil rests on the arms of the bench. (Photo L. Dorfman)

Fig. 4. Modern glassblower's bench. The glassblower rolls the blowpipe back and forth on the arms of the bench while she makes a crease, also known as a jack mark, at the point where the glass will be separated from the pipe. (Photo L. Dorfman [1992])

Roman glassblowing has been undertaken in the past. The problem is that the archaeologist needs to know enough about glass to ask the right questions, whereas the glassblower must be aware of the archaeological reality and the technical limitations of earlier cultures.[17] It is my contention, based on the evidence from ancient vessels, historical research of glassblowing tools, primitive glass furnaces, and my own experience as a glassblower, that neither the tools Harden mentions nor the manufacturing and organizational practices he describes existed when commercial glassblowing began. For example, the glassblower's bench that features prominently in his account—and in most modern reconstruction attempts of ancient techniques—was not invented until the 17th century.[18] Assuming its existence in antiquity thoroughly confuses our understanding of ancient glassworking processes. Another important tool, now indispensable but apparently unknown to Roman glassblowers, is the cross-cutting "scissor-type" iron shears. Many idiosyncrasies of Roman glass vessels, such as the way handles are drawn out thin and folded back and forth at the point of attachment rather than being cut cleanly, may be due to the lack of this tool.[19]

My research leads to the conclusion that more than 100 years of experiments, discoveries, inventions, and improvements separate the first trial infla-

[17] So also T. Gam, "Experiments in Glass. Present and Future," *AnnAIHV* 12, 1991 (Amsterdam 1993) 261–70, esp. 262–63 "Analogies."

[18] Y. Ohira, "Lo scanno e la bardella a Murano e in altre località Europee," *JGS* 29 (1987) 72–80. For a historical evaluation of some of the tools and equipment used by Roman glassblowers: Stern 1995, 19–29; more complete: Stern (in prep.).

[19] Weinberg 35, 66; Stern (in prep.). Stern 1995, fig. 38 shows the modern scissor-type shears used for trimming the rim of a vessel.

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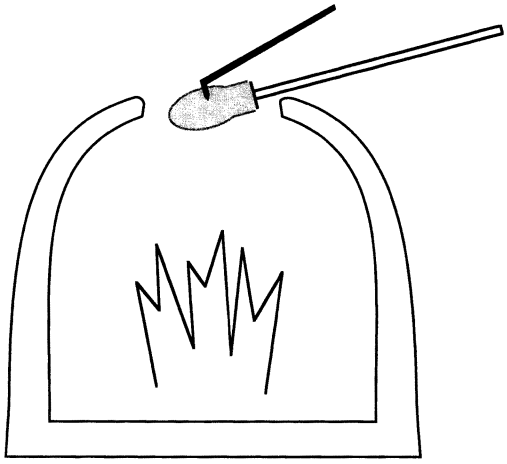

Fig. 5. Core-forming furnace with vertical heat chamber. (Design and drawing D.F. Giberson)

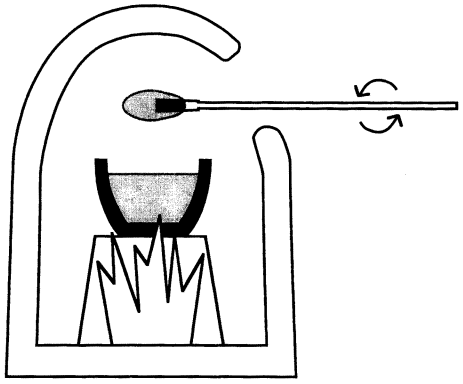

Fig. 6. Reheating in a closed pot furnace with horizontal heat chamber. (Drawing D.F. Giberson)

tion of heat-softened glass[20] from full fledged Roman glassblowing in the second half of the first century. Most of the tools and techniques now taken for granted as integral to the craft were invented during this period. The introduction of a novel type of glassworking furnace with a horizontal heat chamber, the construction of the iron blowpipe, the use of molten hot glass, and the pontil technique for fire-finishing the rim of a vessel, were the most important steps in the development of glassblowing. Most if not all of these techniques were perfected in Italy.

While it is impossible to date these improvements precisely, the essentials can be deduced from various sources. Before the invention of glassblowing, most glassworking operations were probably performed above a vertically rising flame, a set-up that allowed the glassworker to work the glass while he or she was softening (heating) it (fig. 5).[21] The modern glassworker's furnace has a closed, horizontal heat chamber, that is, a heat chamber into which one enters the pipe horizontally. This makes it impossible to manipulate the glass during reheats. The advantage is that, instead of just heating the side turned to the fire, hot air surrounds the glass from all sides (fig. 6). This is important for blowing, because an even distribution of heat allows the glass to expand evenly. The furnace with a horizontal heat chamber was a Roman invention. To judge from Roman clay oil lamps depicting this piece of equipment (fig. 7),[22] it was firmly in place in the third quarter of the first century, when the lamps were made. Their findspots in Asseria (Dalmatia) and Ferrara are consistent with a (north?) Italian origin.

If glassblowing began with inexpensive clay blowpipes, such as appear to be depicted on the two lamps, this could explain the rapid spread of the technique, because the glassblowers themselves could easily make the blowpipes.[23] The hypothesis of the ceramic blowpipe (fig. 8) is attractive; iron tubes are not present in the archaeological record of the Augustan period. A sturdy iron tube was difficult to make with ancient technology. Apart from the expenses involved, the need to custom design and commission an iron blowpipe from a blacksmith un-

[20] Glass tubes pinched closed at the lower end and subsequently inflated through the other end are the earliest evidence for the discovery that heat-softened glass can be expanded by air. On these tubes, excavated in the waste of a glassworker's shop in Jerusalem, assigned to the first half of the first century B.C.: Israeli (supra n. 13) 46–55.

[21] On glassworking facilities before the invention of the closed glassblower's furnace: Stern 1994, 24–25; Stern, "Interaction between Glassworkers and Ceramists," in P. McCray and W.D. Kingery eds., *The Prehistory and History of Glassmaking Technology* (Ceramics and Civilization 8, Westerville 1998) 183–204, esp. 188, 203 (with lit.); D.F. Giberson, *A Glassblower's Companion* (Warner 1998) 19, 47–50.

[22] D. Baldoni, "Una lucerna romana con raffigurazione di officina vetraria: Alcune considerazioni sulla lavorazione del vetro soffiato nell' antichità," *JGS* 29 (1987) 22–29.

[23] The hypothesis of clay blowpipes, based on archaeological considerations and modern workshop experience, was tested in practice and first suggested by E.M. Stern, "Art and Archaeology at the Toledo Museum of Art Glass Crafts Building," *The Glass Art Society 1993 Journal* (Seattle 1993) 70–77, esp. 74–77. See also Stern 1994, 81–85, figs. 156–71; Stern 1995, 39–43, fig. 20 left, figs. 28–32. My thanks are due to Kathleen McCarthy for demonstrating techniques (figs. 2–4, 8, 18, 20, 21). Neither ceramic nor metal blowpipes have been identified in excavations of sites predating the mid-first century.

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Fig. 7. Clay oil lamp from Asseria, depicting ancient glassblower at work before a closed furnace, ca. A.D. 70. (Courtesy Split Archaeological Museum, no. Fc 1094)

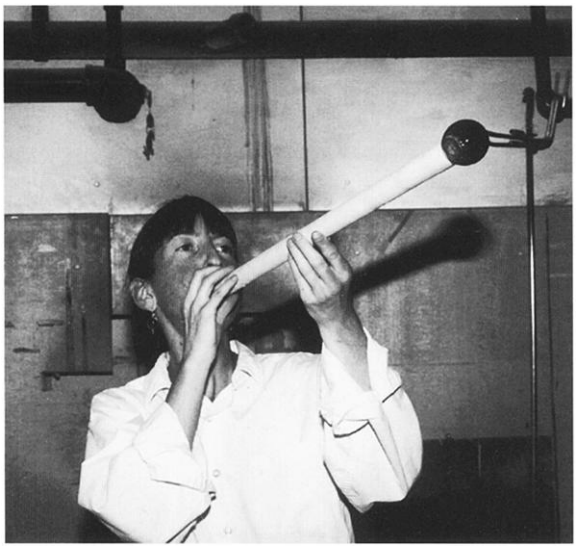

Fig. 8. Blowing with a ceramic pipe. The Toledo Museum of Art glass studio, 1992. (Photo L. Dorfman)

familiar with its construction might have also acted as a deterrent for many glassworkers curious about the new technique.

By the year 70, however, iron blowpipes were in use in many if not all workshops, although they were apparently not used for purposes other than glassblowing. The evidence is indirect. The earliest blown vessels are small bottles weighing 14–60 g and cups up to 166 g. In the second half of the first century large bottles, plates, and cinerary urns with massive handles became common. An urn in Toledo weighs 1066 g without its lid, a cylindrical bottle in the Wolf Collection weighs 572 g (figs. 9, 10). Such vessels were too heavy to be blown with a clay pipe. Their production required a pipe with sufficient tensile strength to carry the weight of the glass. A date before the middle of the first century for the introduction of the iron blowpipe is consistent with the creation of earlier luxury wares. Two magnificent jugs excavated in rich tombs in the vicinity of Milan weigh 495 g and 590 g, respectively (figs. 11, 12).[24] Such heavy vessels are not documented among eastern Mediterranean blown glass of the first half of the first century. The shapes and findspots of early heavy-weight vessels point toward north Italy for the origin of the iron blowpipe.

The earliest physical evidence for the iron blowpipe comes in the form of iron oxidation preserved on the interior of workshop waste from Avenches (mid-first century) and Saintes (ca. 100). The moils preserving the shape of the blowpipe had varying sizes, an indication that the diameters of the blowpipes differed. Remains of an iron pipe with an outer diameter of 1.3 cm and inner diameter of 0.5 cm were excavated at a mid-second to mid-third-century glassworking site at Aix-en-Provence; late Roman blowpipes were excavated in Spain and perhaps in the southern Ukraine.[25] Nothing is known about the length of the Roman iron blowpipe. It may have been relatively short (3 ft. or even less) like the pipes

[24] *Vetro e Vetri* (supra n. 11) 34, no. 1, and figs. 6, 7, pl. V (jug from Dello); 64, 66, no. 3, and figs. 17, 18, pl. XVI (jug from Valeggio Lomellina). See also 30, no. 2, and figs. 2, 4, pl. II: flecked amphora (Isings Form 15) from Carpenedolo (Bs), tomb 1, inv. St. 78987, H 27 cm, preserved weight 335 g. A 26.6 cm tall jug published by B. Czurda-Ruth, *Die römischen Gläser vom Magdalensberg* (Kärntner Museumsschriften 65, Klagenfurt 1979) 131, no. 1013, color pl. 15, weighs over 910 g.

[25] H. Amrein and A. Hochuli-Gysel, "Le soufflage libre du verre dans les ateliers à Avenches (Aventicum) (milieu du 1er s. après J.-C.) et à Saintes (Mediolanum) (fin du 1er s. après J.-C.," *AnnAIHV* 14, 1998 (forthcoming); Velde and Hochuli-Gysel (supra n. 8) 186, fig. 2. Small fragments of iron tubes were excavated at the site of a glassworking furnace at Aix-en-Provence: Rivet (supra n. 9) 356. On late Roman iron tubes, probably blowpipes: J. Lang and J. Price, "Iron Tubes from a Late Roman Glassmaking Site at Mérida (Badajoz), in Spain," *JAS* 2 (1975) 289–96; Stern 1995, 41–42, ns. 26–29; M. Sternini, *La fenice di sabbia. Storia e tecnologia del vetro antico* (Bari 1995) 83–85.

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Fig. 9. Lidded cinerary urn. H. 26 cm; wt. 1,066.0 g (without lid). No pontil scar. Late first to early second century. Western Europe. (Courtesy Toledo Museum of Art, no. 1977.14. Purchased with funds from the Libbey Endowment, gift of Edward Drummond Libbey.)

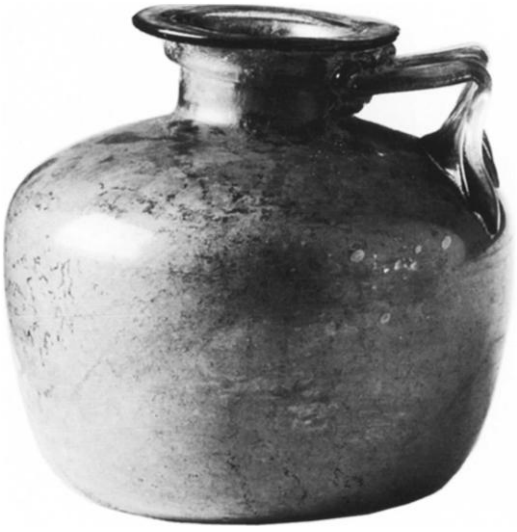

Fig. 10. Cylindrical bottle. H. 14.7 cm; wt. 572 g. No pontil scar. Last quarter of first to first quarter of second century. Probably made in Asia Minor. (Courtesy Ernesto Wolf Collection)

still used in Hebron and other primitive facilities in the eastern Mediterranean.

The vessel's rim was always rough and irregular after separating the glass from the pipe, and finishing the rim presented a challenge. In the earliest years of glassblowing, some mold-blown vessels appear to have been held with a clamp to fire-finish the rim; the necks are distorted and/or show crimp marks.[26] Another possibility would have been to fire-finish the vessel after it was annealed. The glass was so thin that local reheating above a heat source can not be excluded; this technique could explain why many early closed vessels show no distortion or tool marks. The rims of open vessels were usually left unworked if they were very thin (fig. 13), or else ground and polished by cold working after the vessel was annealed (fig. 14). Plates and wide bowls were provided with a blown foot (fig. 15).[27] The artisan used a second paraison (glass bubble), blown against the underside of the vessel, to hold it in the heat, flare it open, and finish the rim (fig. 16).

The pontil technique solved the problem of heat-finishing the rim. Instead of a second paraison the glassworker reattached the vessel with a wad of hot glass that acted as a "glue." This glass leaves a scar, also known as pontil mark, on the bottom of the vessel. Shape, size, and depth of the scar vary; it can take the form of gashes or stand up as a ridge and make the vessel wobbly. Today we usually remove the scar by grinding and polishing. Fortunately ancient glassblowers rarely removed the scars. They provide important clues to the development of the technique, which did not become widely used until the last decennia of the first century. Even then many artisans shied away from reattaching the vessel, as evidenced by many large vessels with intricate rim folding but without a pontil scar (see figs. 9, 10).

The ring-shaped annular scar, the most common scar in East and West throughout antiquity (fig. 17), does not prove the use of a pontil rod (punty). The annular scar can be produced by a punty (fig. 18) but it may also result from reattaching the vessel to the collar of glass that remains on the blowpipe after the vessel is "cracked off." Because the modern glassblower sits on a bench at a distance from the furnace (figs. 2 and 4),[28] reattaching the vessel is now usually done with the help of an assistant, but the ancient glassblower could easily perform this operation by him or herself. Seated on a stool directly in front of the furnace (fig. 19), the artisan cracked off the vessel onto a flat working shelf and then (re)attached the tool to the bottom of the vessel, steadying it

[26] Stern 1995, 20, 21 s.v. Clamp.

[27] Good examples in D.F. Grose, "Early Blown Glass," *JGS* 19 (1977) 20, figs. 3 and 4.

[28] Stern 1995, figs. 37–39.

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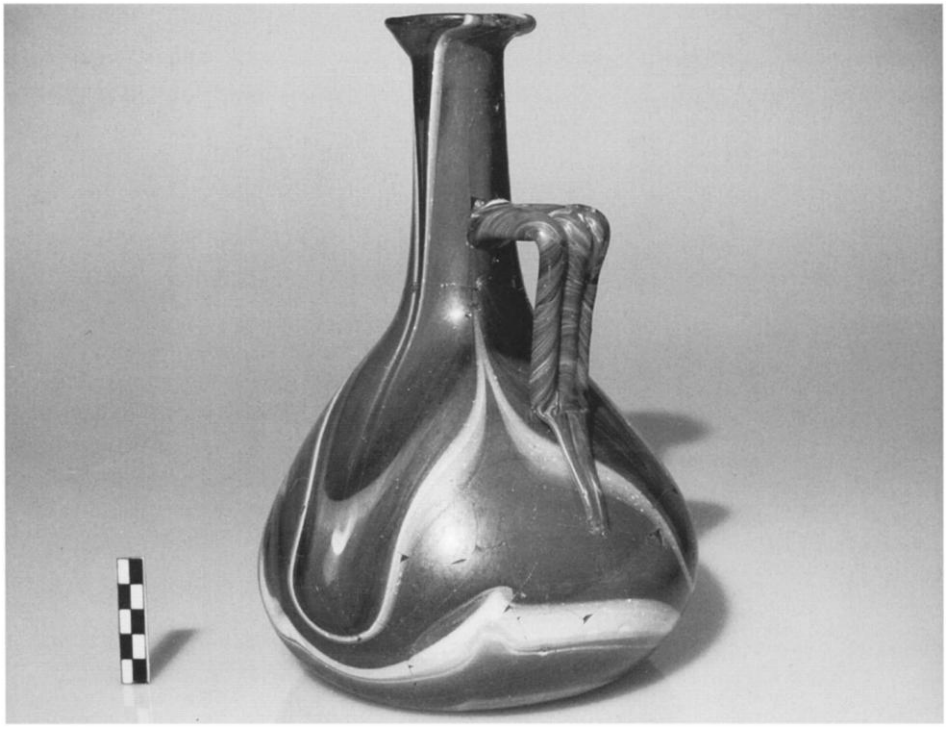

Fig. 11. Jug from Dello (Bs), tomb 3; H. 25 cm; wt. 495 g. No pontil scar. First half of first century. Probably made in north Italy. (Courtesy Soprintendenza Archeologica, Milan inv. St. 122676)

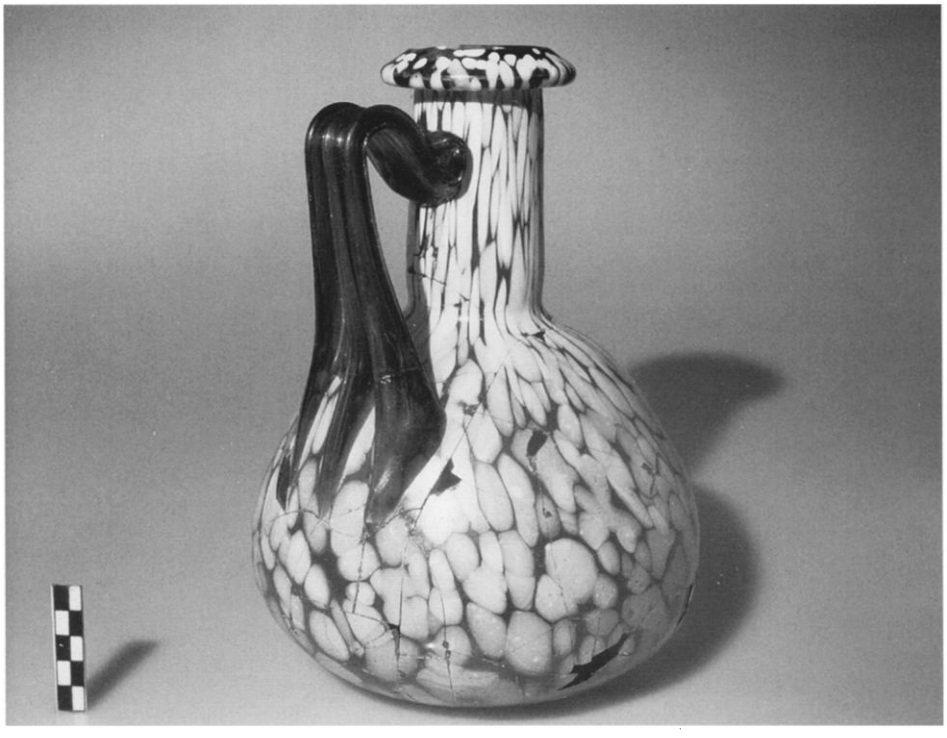

Fig. 12. Jug from Valeggio Lomellina, Cascina Tessera, tomb 54bis; H. 23.7 cm; pres. wt. 590 g. No pontil scar. Mid-first century. Probably made in north Italy. (Courtesy Soprintendenza Archeologica, Milan inv. St. 59234. Gift of Edward Drummond Libbey.)

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against the furnace wall.[29] The shelf, also known as marver, is shown protruding from the furnace in front of the glassblower on the Roman lamp (fig. 7).

The earliest scars known to me are annular scars on vessels excavated at Magdalensberg. They are very rare but predate the year 45.[30] A rich mining and industrial center founded by Roman traders in the southern Alps, Magdalensberg had close ties to north Italy, in particular with large merchant families from Aquileia,[31] which is also where most of the glass came from. The Aquileian connection suggests a north Italian origin for the concept of reattaching the vessel.

The solid scar is positive proof for the use of a punty. Depending on how the glassblower shapes the glass the punty wad will be solid or hollow.[32] A small solid scar of 1 cm diameter, noted in a Flavian context at Augsburg, is proof that the technique of transferring the vessel to a punty was developed before the end of the first century.[33] The punty wad can be made with reheated chunks of glass or by coating the tip of the rod with molten glass. Any or all of the techniques described above could have been used in antiquity.

Fig. 13. Ribbed bowl (*zarte Rippenschale*). H. 5.5 cm; Dm. rim 7.0 cm; wt. 72.4 g. No pontil scar. First half of first century. Probably made in north Italy. (Courtesy Toledo Museum of Art, no. 1923.426. Gift of Edward Drummond Libbey.)

Fig. 14. Hofheim cup. H. 6.4 cm; Dm. rim 7.5 cm; wt. 144.8 g. No pontil scar. Mid-first century. Western Europe. (Courtesy Toledo Museum of Art, no. 1951.376. Purchased with funds from the Libbey Endowment, gift of Edward Drummond Libbey.)

The invention of the iron blowpipe and the construction of the closed furnace were necessary for gathering molten glass. The blowpipe was necessary because iron was the only material that could resist the temperature of molten glass (ca. 1050–1150°C). The closed furnace was the only way to achieve and hold that temperature.

Molten Glass and Recycling

The discovery that molten glass could be blown was nothing less than revolutionary. It was closely related to the equally momentous discovery that broken glass artifacts could be totally remelted, a breakthrough that kindled a literary response in the Flavian period (69–96) equal only to the excitement of Augustan poets about glassblowing. The concept of recycling, with all its social and economic manifestations, reverberated widely in Roman literature and

[29] This technique, still practised in Hebron, is documented in a video made at the Haaretz Museum, Ramat Aviv, and shown in conjunction with the exhibit "Ancient Glass from the Holy Land," Detroit Institute of Arts, 21 November 1998–31 January 1999.

[30] Glass specialists tend to doubt the early date for abandonment of Magdalensberg, but a *terminus ad quem* of 45 has been independently confirmed for all other categories of objects from the site (personal communication H. Dolenz, whom I would also like to thank for permission to study the glass). I noted annular scars on Czurda-Ruth (supra n. 24) 65, no. 515, pl. 3: diameter of scar 1.8 cm, gashes; 87, no. 641, pl. 4, diam. of scar 2.0 cm, gashes. No. 780, pl. 5, has a solid, comma-shaped gash (pontil scar?) with a diam. of ca. 1.5 cm. In addition, two unpublished base fragments excavated in the 1990s have annular scars.

[31] M.R. DeMaine, "Ancient Glass Distribution in Illyricum," *JGS* 25 (1983) 79–86; G. Piccottini and H. Vetters, *Führer durch die Ausgrabungen auf dem Magdalensberg* (Klagenfurt 1990); G. Piccottini, "Gold und Kristall am Magdalensberg," *Germania* 72 (1994) 467–75; H. Dolenz, *Eisenfunde aus der Stadt auf dem Magdalensberg* (Kärntner Museumschriften 75, Klagenfurt 1998).

[32] Glassblowers now make a hollow punty for a variety of reasons: to diminish the size of the scar, to facilitate separation from the punty, to attach a punty to a piece with a pointed bottom, etc.

[33] Personal communication A. Rottloff (1997). On the glass from Augsburg: A. Rottloff, "Zwei bedeutende Fundkomplexe römischer Gläser aus Augusta Vindelicum-Augsburg," *AnnAIHV* 13, 1995 (Lochem 1996) 163–74. Compare eastern Mediterranean mold-blown bottles: Stern 1995, nos. 120–128, solid pontil scar illustrated on p. 191.

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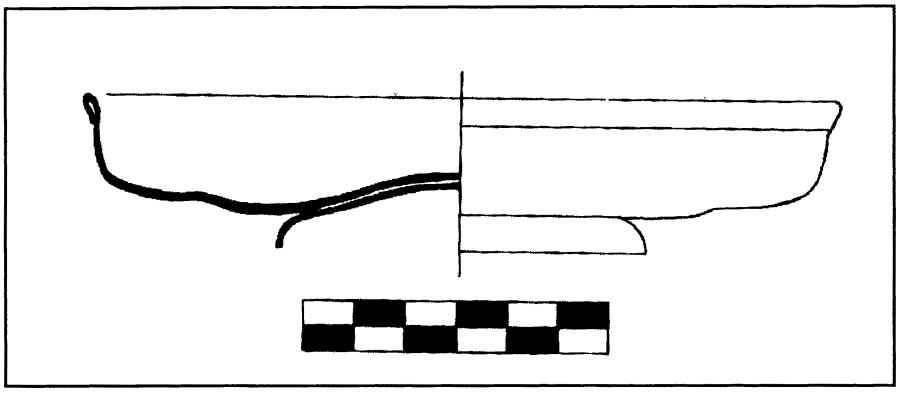

Fig. 15. Plate with blown foot from Cosa, Atrium Publicum, no. CE 1965. Dm. rim ca. 14 cm. Before A.D. 40/45. Italian. (After D.F. Grose, "Early Blown Glass: The Western Evidence," *JGS* 19 [1977] 20, fig. 3c)

caught the imagination of all classes of society. Recycling became a poetical topos for Flavian poets such as Martial (*Epigr.* 1.41.3–5; 10.3.3–4), Statius (*Silv.* 1.6.73–74), and Juvenal (*Sat.* 5.47–48).

Recycling had already been common before the invention of blowing, but it was on a small scale and did not involve remelting. Glassworkers and artisans in related fields reused fragments of precious colored glass vessels and sandwich gold-glass. Bits of broken glass, including bicolored pieces, were included in early architectural mosaics.[34] Curved glass vessel fragments formed the eyes inlaid in bronze statues and mummies.[35] Scraps and chips from mosaic canes were used as backing to mosaic glass tiles[36] and tesserae made from broken sandwich gold-glass vessels decorated early mosaic glass dishes.[37]

Literary evidence suggests that the discovery that broken glass can be totally remelted took place in the early Flavian period. Pliny does not seem to have been aware of this property of glass. He wrote (*HN* 36.199): *fragmenta teporata adglutinantur tantum, rursus tota fundi non queunt* "broken fragments can only be made to stick to each other, they can not be totally remelted." Thus we can probably date the discovery to some time between ca. 70, when Pliny had finished most of his *Natural History*, and Martial's *Epigrams* in A.D. 86. If a basket full of broken glass excavated at Pompei may be interpreted as fragments collected for remelting, the discovery may date before 79.[38] The realization that glass can be totally remelted led to the deliberate collecting of broken vessels, and recycling became synonymous with remelting. At this time strongly colored glass was also going out of fashion;[39] most Roman glass of the last quarter of the first century and the following centuries was either natural bluish green or colorless. This could be remelted without the risk of becoming an indistinct muddy color as would have been the result of remelting mixed fragments of colored glass.

To blow molten glass it must be held at a constant high temperature (ca. 1050–1150°C) for the duration of the work. Such a high temperature can be achieved only with sophisticated pyrotechnology. The furnace design is complicated by the fact that the working port emits heat. Modern furnaces have a shield or door which the glassblower can open and close quickly for gathering and reheating. Perhaps Roman furnaces also had a door, but we do not know. The sophistication of the Roman furnace can best be appreciated by comparing the quality of ancient glass vessels to those made in primitive furnaces in the eastern Mediterranean. Like the Roman glassblower's furnace, furnaces in Herat (Afghani-

[34] F.B. Sear, *Roman Wall and Vault Mosaics* (Heidelberg 1977) 40.

[35] Personal observation, April 1983, Graeco-Roman Museum, Alexandria, inv. 14475/20818 and 20847. One of the inlaid glass eyes preserves cut grooves on the reverse.

[36] Stern 1994, 63.

[37] Stern 1994, 109–10, 112.

[38] A. Pasqui, "La villa pompeiana della Pisanella presso Boscoreale," *Monumenti Lincei* 7 (1897) 518 (quoted after J.-P. Morel, "La ceramica e il vetro," in F. Zevi ed., *Pompei 79* [Naples 1979] 256). Dio Cassius's statement (60.17.6) that the Roman emperor Claudius made citizenship so widely available that one could obtain it "for a piece of broken glass" cannot be used to date the beginning of recycling to his rule (37–54). Dio wrote in the late second to early third century when recycling was so common that "broken glass" had become an idiomatic expression for indicating cheapness.

[39] The reasons for the change to colorless glass were probably unrelated to remelting: Stern 1995, 186.

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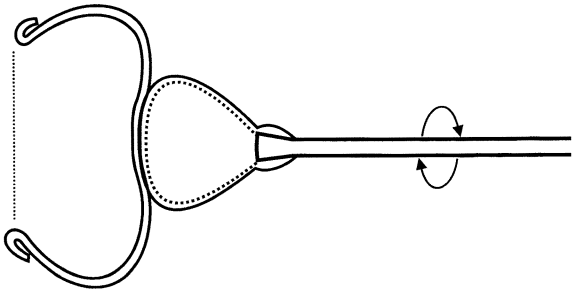

Fig. 16. Using a second bubble to flare open the rim of a dish. (Drawing A. and L. Marty)

stan), Damascus, Hebron, and Cairo still functioning in the 1960s and 1970s remelted broken glass,[40] but the quality of their output was poor. The glass is bubbly and full of striae and other impurities, in part because they did not achieve the high temperatures required for complete fusion. The temperatures achieved by modern furnaces at Cairo and Herat were around 800°C.

Not all Roman glassblowers worked with molten glass. Many glassworkers continued to pick up preheated chunks of glass (fig. 20) and soften them at the tip of the tool (fig. 21), as they had done since

Fig. 17. Ring-shaped pontil scar, gashes. Fragment of plate of Isings Form 46a, from Augsburg. Augsburg, Glasschicht, no. 3080 L. Flavian. (Photo A. Rottloff)

Fig. 18. Hollow punty wad. (Photo L. Dorfman)

the beginning of glassworking in the second millennium B.C. Individual chunks of glass may be heated even without a furnace, above a simple fire-pot. The temperature needed for softening glass to a workable state is not more than ca. 900–950°C, possibly even lower.[41] Very little glass is wasted in the process because there is no crucible to which the glass can adhere and less glass remains on the pipe. Molten glass was not commonly used in bead making: bead makers needed so many different colors in small amounts that heating individual chunks of raw glass or fragments of broken colored glass was always more economical than melting glass in a crucible.[42]

The glassblower starting with a chunk of glass took care not to get it too hot, because then the glass would drip off the pipe and be wasted. The discovery that drippy hot glass could actually be manipulated and blown must have come as a shock—probably equal in intensity to the disbelief of glass historians when they were first confronted with the concept of blowing a chunk of glass.[43] Working with molten glass required a total rethinking of techniques. The glassblower gathering drippy hot glass has to cool the outer skin of the glass on his pipe before it can

[40] Chafic Imam, "L'artisanat du verre en Syrie," *AnnAIHV* 3 (Liège 1964) 184–90; D. Charlesworth, "A Primitive Glass Furnace in Cairo," *JGS* 9 (1967) 129–32; G. Lehrer, *Hebron City of Glassmaking* (Museum Haaretz, Tel-Aviv n.d., ca. 1970); M. Reut, "Le verre soufflé d'Herat," *StIr* 2.1 (1973) 94–111; N.H. Henein, *Le verre soufflée en Egypte* (Cairo 1974); L. Taborelli, "Un modo arcaico di produzione vetraria: Viaggio nel tempo al seguito di una fonte contemporanea," in A. Avanzini ed., *Profumi d'Arabia, Atti del convegno Pisa 1995* (Saggi di Storia Antica 11, Rome 1997) 149–66. A primitive furnace in Turkey, used exclusively to produce nonblown objects, such as beads and bangles, is described by Ö. Küçükerman, *Glass Beads. Anatolian Glass Bead Making* (Istanbul 1988).

[41] The temperature depends on the composition of the glass. On the temperatures needed to soften ancient glass: Stern 1994, 21–23 and Stern 1995, 34–36. Giberson (supra n. 21) 47 emphasizes the fact that "the use of hot glass as an application does not in itself prove the use of a pot of hot glass."

[42] On ancient bead making techniques: Gam (supra n. 17).

[43] E.M. Stern, "Glass Working before Glass Blowing," *AnnAIHV* 12, 1991 (Amsterdam 1993) 21–31, esp. 22–23.

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Fig. 19. Marver(ing surface) adjacent to furnace. Hebron glassblower at work. (After G. Lehrer, *Hebron City of Glassmaking* [Tel Aviv n.d.])

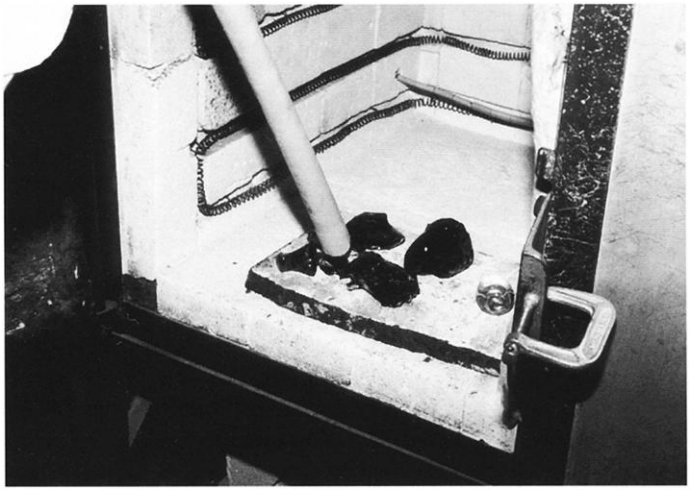

Fig. 20. Picking up a preheated chunk of glass at the tip of a ceramic blowpipe. The Toledo Museum of Art glass studio, 1992. (Photo L. Dorfman)

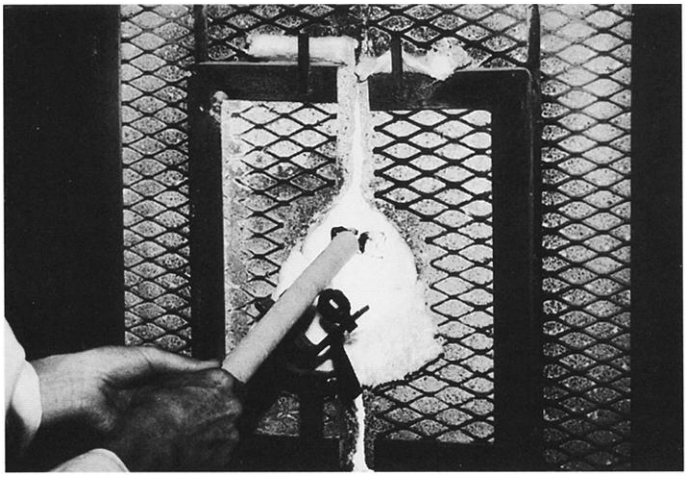

Fig. 21. Heating a chunk of glass at the tip of a ceramic blowpipe prior to blowing. The Toledo Museum of Art glass studio, 1992. (Photo L. Dorfman)

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be blown. The advantage of working with molten glass is that cooling the skin of a hot gather takes less time than heating a chunk; it is also easier to blow large vessels, because one can dip the pipe several times into the molten glass to gather new glass over the glass already on the pipe.

Archaeological and literary evidence suggests that in antiquity, working with molten glass was more common in Italy and western Europe than in the eastern Mediterranean, where glassblowers as late as the fourth century still picked up individual chunks, known in Greek as *harpazein bolon* "chunk gathering."[44] This may have been due to a problem securing fuel in areas with little or no wood. Even if ancient furnaces stoked as diverse an assortment of materials as traditional kilns in south Italy and Sicily in the 1950s and 1960s—branches, roots, trimmings, as well as straw, olive husks, shavings, and sawdust (whatever happened to be available)[45]—it would still have been a daunting task to assemble sufficient fuel to work with molten glass. The calorific value per gram of these materials is constant, about 4.5 Kcal for dry wood, less if the wood is green, but the volume of fuel and the energy spent on gathering it depends on the species of tree and type of material (brush or heartwood).[46] The amount of fuel needed for a primitive glassworker's furnace in modern Cairo is enlightening: it stoked one-third of a ton of wood per day, using mostly old railroad ties and wood from disassembled ships,[47] that is, compact materials.

Ancient artisans were slow to discover that glass can be totally remelted because they did not make their own glass. They bought it as solid ingots or chunks and had little understanding of how the material was made. The reason for this lay in the structure of the glass industry.

THE STRUCTURE OF THE GLASS INDUSTRY

In antiquity, glassmaking and glassworking were two separate crafts. This had been the case from the very beginning in the second millennium B.C. and remained customary throughout antiquity and into the Middle Ages.[48] The division into primary workshops for making the material and secondary workshops for working and shaping the glass had important consequences for the structure of the Roman glass industry. It is generally accepted that few primary workshops existed in the centuries prior to the invention of glassblowing. A recent analysis of Roman glass from different areas and different centuries concludes that the chemical composition is so uniform that the same source of sand must have been used to make the glass.[49] If this conclusion is correct, primary glassmaking was probably still concentrated within a very few areas.

Pliny (*HN* 36.190) mentions as primary glassmaking areas the Syro-Palestinian coast (confirmed for the Byzantine period by excavations of huge glass tanks in Israel),[50] as well as Campania, Spain, and Gaul (*HN* 36.194). Strabo (16.758) mentions Egypt (confirmed by archaeological remains, although the dating is less certain).[51] The hypothesis that glass was made only in a small number of primary workshops in the Roman Imperial period is consistent with the fact that numerous remains of glass furnaces excavated in western Europe and Britain have all been identified as secondary workshops (where glass was shaped into objects).

Glassblowing, unlike other industries associated with fire (pottery, bronze, and metalworking), did not develop into a large-scale enterprise in antiquity and the early Middle Ages, in spite of a formidable output. This was probably due entirely to physical restraints. Ancient depictions show that the

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[44] *P Oxy.* 50, no. 3536, line 3. On the literary and archaeological evidence for this technique: E.M. Stern, "A Fourth Century Factory for Gathering and Blowing Chunks of Glass?" *JRA* 5 (1992) 490–94; Stern 1994, 28; Stern 1995, 36–37; Stern, "Glassblowers in Greek Poetry," *AJA* 101 (1997) 342–43 (abstract).

[45] R. Hampe and A. Winter, *Bei Töpfern und Zieglern in Süditalien Sizilien und Griechenland* (Mainz 1965) 196; Giberson (supra n. 21) 50 mentions straw, with documentary evidence for this practice. On stoking a mixture of locally available materials including palm fronds, see also C.M. Jackson et al., "Glassmaking at Tell el-Amarna: An Integrated Approach," *JGS* 40 (1998) 11–23, esp. 19–21.

[46] DeLaine 113.

[47] Henein (supra n. 40) 10.

[48] On the separation of the glass industry into two separate branches: E.M. Stern, "The Production of Glass Vessels in Roman Cilicia," *KölnJb* 22 (1989) 121–28, esp. 121–23; Stern 1994, 19–27.

[49] Nenna et al. (supra n. 8) 81–87; D. Foy and M. Picon, "Lingots de verre en Méditerranée occidentale (3e siècle avant J.-C.–5e siècle après J.-C.): Approvisionnement et mise en oeuvre," *AnnAIHV* 14, 1998 (forthcoming). On glassmaking: Stern 1995, 23–24. New insights can be expected from M.-D. Nenna ed., *Ateliers de verriers. Découvertes récentes* (Travaux de la Maison d'Orient, Lyon 1999, in press), especially the contributions by M.-D. Nenna, Y. Gorin-Rosen, M. Picon, and M. Vichy (brought to my attention by M.-D. Nenna).

[50] Infra n. 261.

[51] Nenna et al. (supra n. 8) 85–86; M.-D. Nenna, "Ateliers de production et sites de consommation en Egypte: Bilan de cinq années de recherches 1993–1998," *AnnAIHV* 14, 1998 (forthcoming).

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Roman glassworking furnace was small[52] (figs. 7, 22). The interior circumference was approximately 45–65 cm, a measurement confirmed by excavated remains at Avenches and elsewhere.[53] The furnace had one working port. Because each glassblower needed his or her own working port to reheat the glass on the pipe while he or she was actually making an object, the number of working ports dictated how many glassblowers could work simultaneously at one furnace.

Although excavations often find more than one furnace in close proximity, it is not clear to what extent they operated simultaneously. For example, at Avenches, where four furnaces were in use between 40 and 70, two overlap, suggesting rebuilding, a task that must have often been necessary (annually?) because of heavy wear on the walls of the furnace.[54] Multiple furnaces may have been necessary in order to blow on a daily basis. A primitive glassblowing furnace at Herat could operate only every other day because the furnace needed 24 hours to cool down after a day's work. When demand suddenly increased the owner built a second furnace to be able to blow every day.[55]

Other impediments to expanding into large scale operations included the size of the crucible containing the molten glass and the amount of space available for annealing, the slow cooling process necessary to avoid creating stress in the glass that might cause it to crack. Depending on the thickness of its walls, a glass vessel anneals in about 18–20 hours. It cannot be safely removed from the space reserved for annealing until the glass reaches room temperature.[56] Adjacent to one of the furnaces at Avenches was a rectangular structure identified as an annealing area. Perhaps the annealing chamber was tacked onto the main structure and heated by the same fire as the furnace itself, as it is commonly organized in primitive furnaces. Rekindling and bringing the furnace up to temperature in these primitive furnaces takes about two hours if the furnace has been used

Fig. 22. Fragment of clay oil lamp from Carthage. Private Collection. End of fourth to early fifth century.

the previous day; otherwise it can take up to three hours. An additional two hours are reserved for melting the glass (i.e., the broken glass vessels).[57] To achieve the relatively pure glass seen in many Roman objects, the time allotted to melting would probably have been longer.

In view of the particular exigencies of the métier, it is unrealistic to assume that ancient glassblowing was a large-scale industry comparable to the pottery industry—with hundreds of employees or even slaves laboring in one establishment.[58] Available pyrotechnology made it impossible to enlarge the ancient glass furnace so that it could accommodate more than one working port. In theory it would have been possible to create a series of small furnaces like the metal workshops at Magdalensberg, but even there inscriptions indicate that individual shops belonged to individual owners and/or managers,[59] and no comparable agglomeration is known for Roman glass furnaces. Large-scale glass industry began in 15th-century Europe, when huge furnaces with multiple working ports enabled numbers of glassblowers to work simultaneously. Earlier medieval illustrations

[52] B. Caron and C. Lavoie, "Un fragment de lampe représentant un four verrier," *JGS* 39 (1997) 197–98.

[53] Four first-century furnaces at Avenches, inner diameter 50–65 cm: Morel et al. (supra n. 8) 5–6, figs. 3–7 (with refs. to similar size furnaces at Martigny and Kaiseraugst); furnace at Aix-en-Provence, postdating 150, inner diam. 45 cm, outer diam. ca. 75 cm: Rivet 1992 (supra n. 9) 349. Although a fourth-century glassworking furnace excavated at Jalame was rectangular and covered a larger area, ca. 2.40 × 3.60 m, there is no indication that it had more than one working port: Weinberg 28–33.

[54] Morel et al. (supra n. 8) 5–6, figs. 3, 4, 6, and 7.

[55] Reut (supra n. 40) 107.

[56] Annealing appears to have been a major problem in Roman workshops. At Jalame, many fragments testify to accidents during the annealing process: Weinberg 35.

[57] Reut (supra n. 40) 104.

[58] F.K. Kiechle, "Die Struktur der gewerblichen Glaserzeugung in der frühen Kaiserzeit," *AnnAIHV* 6, 1973 (Liège 1974) 53–64. An *AJA* reviewer notes that large-scale enterprises are also uncharacteristic of the pot industry. Much pottery and metalworking was done in small-scale units.

[59] Piccottini and Vetters (supra n. 31) 60–63; Dolenz (supra n. 31) 15–37.

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of glassblowing still show a solitary master at the furnace.[60] Literary evidence attests that this was still the norm in the 12th century. Glassblowers took turns blowing but did not blow simultaneously (see below, *The Glassblowers*).

To gain a sense of the ancient glassblower's output, it is useful to look at the output of glassblowers working at primitive furnaces. The glassblower in Herat produced about 100 vessels per day.[61] The furnace in Cairo accommodated three pots of molten glass and three working ports. Depending on the size of the vessels and the complexity of their shapes (handles, spouts), one day's production utilizing the two larger pots could be either 100 large and/or complicated vessels or 100 medium-sized vessels; one working port sufficed for the production of 250 small vessels.[62]

It is not known how many days per year the ancient glassblower worked. Recent calculation of the Roman working year suggests 220 days for a seven month season, 290 days for a nine month season.[63] If the glassblower had to let the furnace cool down entirely between blowing cycles (see above), he or she could blow only every other day. For calculating the ancient glassblower's minimum output, it is here assumed that blowing was seasonal and took place on 110 days for a 12-month year of 220 days. Based on the examples of the glassblowers in Herat and Cairo, the output averaged 100 vessels per day or 11,000 per year.[64] This works out to 330,000 vessels in 30 years! Although glassblowing is not only dangerous but also unhealthy because of poisonous fumes, such a long period of activity would not have been impossible. The tombstone of the *opifex artis vitriae* "glass artist" Julius Alexsander records his death in Lyon at the venerable age of 75 after 48 years of happy marriage.[65]

The size and design of the ancient glassworking furnace imposed certain physical restrictions. This affected many aspects of organization of the industry, from the number of people who could work simultaneously in one shop and their relationships

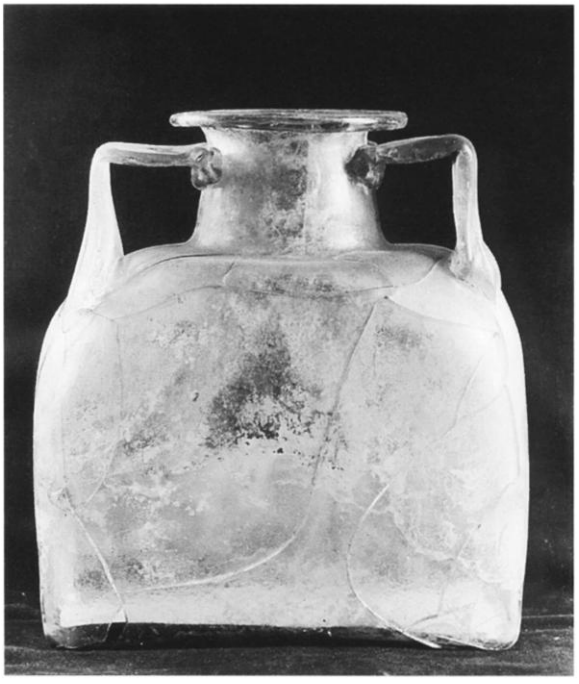

Fig. 23. Rectangular bottle from Linz, grave 99a. H. 28.5 cm. Grave dated first half of second century. Made in Aquileia. (Courtesy Oberösterreichisches Landesmuseum)

with each other, to external transactions such as buying raw glass and the marketing and selling of the finished product.

The Glassblowers

It has been suggested that the economy of the Roman empire can be compared to the western European economy between 1400 and 1800.[66] However, this may not apply to glassmaking and glassworking, since Roman workshop practises differed considerably from those common in late medieval and early industrial Europe.[67] The limited number of people who could blow at one furnace has been noted above. Another difference regards the gender of the glassblowers. Whereas until very recently glassblow-

[60] R.J. Charleston, "Glass Furnaces through the Ages," *JGS* 20 (1978) 9–33, esp. 11, fig. 1 The earliest furnaces with multiple workports appear in illustrations dated to the late 15th century (Charleston 13, figs. 2, 3).

[61] Taborelli (supra n. 40) 159.

[62] Henein (supra n. 40) 38. It seems strange that there would have been no difference between the number of large and medium-size vessels. Production included some 56 shapes with diameters varying between 55 and 4 cm; the height of bottles varied between 23 and 6 cm. The glassblowers blew five days per week, from 10 a.m. to 10 p.m. breaking only for meals.

[63] DeLaine 105–106; the figures of 220 and 290 include one day off in eight.

[64] Taborelli (supra n. 12) 223 with n. 6 calculates a maximum output of 36,000 vessels per year for one furnace with two master blowers and one assistant blowing on alternate days.

[65] D. Foy and G. Sennequier, *A travers le verre du moyen âge à la renaissance*, exhibition catalogue, Musée des Antiquités de Seine-Maritime à Rouen (Rouen 1989), 61, 62, no. 8.

[66] W.V. Harris, "Between Archaic and Modern: Some Current Problems in the History of the Roman Economy," in Harris (infra n. 84) 11–29, esp. 15.

[67] The main concern of this paper is vessel glass. Comparative evidence regarding architectural glass is noted only where it is relevant to the topic. Later documents that might elucidate practices in Roman glassblowing are brought into the discussion where evidence for the Roman period is inconclusive.

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Fig. 24. Detail of underside of fig. 23, 25 × 13.4 cm. Signed SENTIASE/CUNDAFA/CITAQ[uileia] VITR[earia]. (Courtesy Oberösterreichisches Landesmuseum)

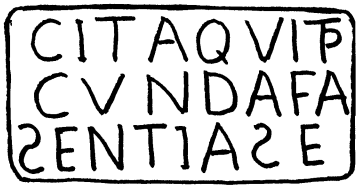

Fig. 25. Detail of fig. 23. Drawing of signature, beginning in bottom line, left.

ing in Europe was an exclusively male occupation, the names of several women glassblowers active in the first century are known: Sentia Secunda had a shop in Aquileia (figs. 23–25); Neikais worked in the Greek-speaking eastern Mediterranean.[68]

A number of glassblowers of the Roman period are known by name, but little is known about their financial and social positions. The names of two glassblowers inscribed on a Roman pottery lamp (fig. 7) are of interest because they suggest the glassblowers were *liberti*, freedmen. Next to the glassblower blowing a tall-necked bottle appears the name TRELLUS; his assistant's name is ATHENIO[69] suggesting he (or his ancestor) hailed from Athens. Since the lamps were made in Italy, we may assume the scene represents a workshop in Italy.

In the eastern Mediterranean, one glassblower stands out above all others: Ennion. His name has been identified as a Hellenized Semitic name.[70] Ennion specialized in mold-blown tablewares.

[68] P. Karnitsch, "Der römische Urnenfriedhof," *Jahrbuch Stadt Linz* 1952, 385–489, esp. 437–46, a discussion of two rectangular bottles, each with a different base molding, from women's graves 99a and 99c. I would like to thank A. Rottloff for sending a copy of the relevant pages. See also E.M. Stern, "Women Glassblowers in the Roman Empire," *AJA* 97 (1993) 338 (abstract); Stern 1995, 100–101, no. 5; Stern, "Neikais—A Woman Glassblower of the First Century A.D.?" in G. Erath, M. Lehner, and G. Schwarz eds., *Komos Festschrift für Thuri Lorenz zum 65. Geburtstag* (Vienna 1997) 129–32, pls. 27–28.

[69] Foy and Sennequier (supra n. 65) 109–10, no. 44 state that the names were scratched into the clay after firing, but that is not what is said by M. Abramic, "Eine römische Lampe mit Darstellung des Glasblasens," *BJ* 159 (1959) 149–51, who first published the lamp and studied the original object. Like the lines representing flames at the top of the furnace the inscriptions were added before firing, when the clay was leather hard.

[70] G. Lehrer, *Ennion, a First-century Glassmaker*, exhibition catalogue, Haaretz Museum (Ramat Aviv 1979) 14; it is also known from a third-century builder's inscription at Damascus: *SEG* II, 829. On Ennion see also Harden et al. (supra n. 16) 164–66, nos. 86, 87; Y. Israeli, "Ennion in Jerusalem," *JGS* 25 (1983) 65–69; Stern 1995, 69–73; D.P. Barag, "Phoenicia and Mould-blowing in the Early Roman Period," *AnnAIHV* 13, 1995 (Amsterdam 1996) 77–92. Ennion's floruit was in the first half to mid-first century.

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Glass vessels showing his mold-blown signature in Greek, *Ennion epoiese*, "Ennion made (me)," have been found throughout the Mediterranean from Israel to Spain as well as on the north coast of the Black Sea. The notably wide distribution of his products is a measure of his success, not only as a glassblower but also as a businessman who was either familiar with all the intricacies of long distance trade or else knew how to find the right partner(s) for this venture.

It is not easy to assess the economic realities of glassworkers from Roman tax laws of the third and fourth centuries. If a statement ascribed to Lampridius in the *Historia Augusta* can be trusted (SHA *Alex. Sev.* 24.5), glassworkers (*vitriarii*) were prosperous enough in the early third century to be included with other craftsmen who were taxed in order to pay for the emperor Alexander Severus' building projects. Vitriarii here probably refers to those who made architectural glass (windows, mosaics)—increasingly in demand for large public buildings—rather than vessel glass. In the small Egyptian town of Oxyrhynchus, for example, 6000 pounds of glass, costing a total of 1320 talents, went into the "warm baths" (Gk. *thermon*) of the city's public bath.[71] The decoration of the walls and vaults of the baths of Caracalla in Rome included 16,900 m^2 of glass mosaic.[72] Aurelian (270–275) taxed glass and other commodities imported from Egypt into Rome (Vopiscus *Vit. Aurel.* 45.1),[73] perhaps to protect local craftsmen. Italy and Rome were just beginning to recover from a century-and-a-half long malaise that had plagued all segments of private life.[74]

In August 337 *diatretarii*, perhaps "engravers and/or cutters," and vitrarii, along with other groups of skilled laborers and artisans, professionals and semi-professionals, were exempted from personal taxes. The law, which was probably issued by one of emperor Constantine's sons,[75] remained in force into the sixth century. Its phrasing suggests that the glassworkers may have been bound to their place of residence and trade by a hereditary tie: "We decree that the workers in the crafts included in the list appended below, *abiding in the individual communities*, should be exempted from all kinds of compulsory services, as leisure should be employed for learning their crafts thoroughly in order that they wish both to become more skilled themselves and *to train their sons*."[76]

Before the Constantinian edict, wares originating in different parts of the empire were made using specialized techniques such as snake-thread glass, sandwich gold-glass, and flasks within flasks. Such techniques are so complicated that they presuppose contacts between glassblowers themselves.[77] The hypothesis that in the Roman empire glassblowers moved about freely, setting up shop where there was a market for their products, is supported by epigraphical evidence. The glassworker Julius Alexander, who died at Lyon ca. 200, hailed from Carthage.[78] The fourth-century restriction of glassblowers' movements is consistent with a new phenomenon: "international" fashions in glass are characterized primarily by the imitation of elements that a glassblower can duplicate just from seeing an object made elsewhere.

The organization of the glass industry was probably not uniform throughout the Roman empire. In the northwest provinces, for example, workshops were characteristically situated on the edge of town, an arrangement that was destined to become dominant in medieval Europe.[79] To judge from the discovery of a Byzantine workshop in the center of town at Bet She'an, glassblowing in the eastern Mediterranean was not always relegated to the outskirts.[80]

In the temperate climate of Europe, glassblowers would have had no difficulty working year-round. In the eastern Mediterranean, where summers were harsh and hot, blowing may have been a seasonal occupation reserved for the winter. The summer months could have been occupied with marketing

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[71] *P Oxy.*, vol. 45, no. 3265 (infra n. 130).

[72] DeLaine 180–81.

[73] On authorship and credibility of events cited in the *Hist. Aug.*: *KlPauly* (Munich 1979) 2.1191–93.

[74] C. Panella, "Le merci: Produzioni, itinerari, destini," in A. Giardina ed., *Società romana ed impero tardo antico* 3: *Le merci. Gli insediamenti* (Bari 1986) 431–59; infra n. 164.

[75] The edict was issued by Constantine II, according to O. Seeck, *Regesten der Kaiser und Päpste für die Jahre 311 bis 476 n.Chr.* (Stuttgart 1919) 185. On the receiver, Valerius Maximus, Praetorian Prefect of Dalmatius Caesar (?), see A.H.M. Jones, *The Prosopography of the Later Roman Empire* 1: *260–395* (Cambridge 1971) 590–91.

[76] *Artifices artium brevi subdito comprehensarum* per singulas civitates morantes *ab universis muneribus vacare praecipimus, si quidem ediscendis artibus otium sit adcommodandum; quo magis cupiant et ipsi peritiores fieri* et suos filios erudire. *Cod. Theod.* 13.4.2; *Cod. Iust.* 10.66.1; author's emphasis. On the edict: Trowbridge (supra n. 3) 119 with n. 34; E.M. Stern, *Ancient Glass at the Fondation Custodia (Collection Frits Lugt) Paris* (Archaeologica Traiectina 12, Groningen 1977) 156–58.

[77] Stern (in prep.). On migrating Syrian glassworkers, infra n. 263 (snake-thread), n. 264 (flask within flask).

[78] Supra n. 65.

[79] Stern (supra n. 76) 152–55. For recent publications of Roman workshops on the outskirts of towns: Rütti 150–52 (Augst); Rottloff (supra n. 33) 170 (Augsburg).

[80] Gorin-Rosen 1998 (supra n. 9) 27–29.

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and selling the glass, ordering new supplies, and rebuilding the furnace, or by activity in some other field. Such a seasonal division of work has been noted for Cypriot potters.

Business Relationships

Business relationships appear to have differed as a result of the very different conditions in the eastern Mediterranean, Africa, and Europe during the formation of the empire. In the west, where the Romans generally had a higher level of organizational, technical, and business skills than the populations in the areas they annexed and converted into provinces, powerful senatorial families with freedmen and slaves as business managers and agents dominated production lines in several industries. A good example is the metal industry at Magdalensberg.[81] It is conceivable that the production of architectural glass was organized along lines similar to those in the metal and clay industries (bricks and tiles), but archaeological evidence is lacking. In this connection, it is unfortunate that we do not know whether the base moldings on the underside of prismatic glass bottles refer to the makers of the bottles or to those who produced their contents.[82] If the moldings refer to the glass workshop, the distribution pattern of bottles carrying the name of C. Salvius Gratus might be consistent with the hypothesis of branch workshops, one in north Italy, the other in Augsburg, both active in the late second to early third century.[83]

Most research on business practices has focused on conditions in Italy and the western part of the Roman empire.[84] The following observations and remarks concentrate on the eastern Mediterranean.

In the eastern provinces glassworking already boasted an established tradition of business practices long before the Romans arrived. The mold-blown signatures on certain glass vessels appear to indicate that individual glassworkers entered freely into business partnerships. The group of Iason, Meges, and Neikais, all three of whom specialized in mold-blown bulbous beakers of one specific type and blown in molds of exactly the same technical construction, is the most obvious example. The Sidonians who migrated to Italy and made skyphoi with stamped handles are another group which may have formed partnerships.[85] In third-century Egypt glassworkers organized locally in guilds.[86]

One recent hypothesis is the possibility of the exchange of molds for mold blowing, implying "a series of local workshops, perhaps trading actual molds among themselves."[87] Originally suggested to replace Harden's hypothesis that the glassblower Ennion relocated in midcareer from the Syro-Palestinian coast to north Italy,[88] the concept of mold exchange may be comparable to the production of signed clay lamps (*Firmalampen*) in the western part of the Roman empire.[89] There is, however, no evidence that branch workshops played an active role in the eastern Mediterranean, not even in the pottery industry.[90] Elsewhere I have argued that the distribution pattern of Ennion's products and other early eastern Mediterranean mold-blown wares is indicative of long distance trade.[91] Ennion's enormous output—over 30 vessels preserving his mold-blown signature are known—may very reasonably be the production of one artist (see above).

Glassblowing and pot making are similar in that both industries produced household containers and tablewares. Yet it is not clear to what extent business practices of Roman glassblowers compare with those of Roman potters. Several contracts from Roman Egypt provide details regarding the lease of facilities and equipment to potters. The exact juridical inter-

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[81] Supra ns. 31, 59.

[82] On the problems of names, infra pp. 467–69.

[83] A survey of north Italian findspots casts doubt on the hypothesis that the bottles marked by C. Salvius Gratus were made in Aquileia: E. Roffia, "Osservazioni su alcune bottiglie in vetro con marchio di C. Salvius Gratus," *Rivista Archeologica dell'Antica Provincia e Diocesi di Como* 163 (1981) 115–29, pls. I–V; G.M. Facchini, "La circolazione dei vetri romani nella Cisalpina: il ruolo di Calvatone-Bedriacum," *Quaderni del Giornale Economico* Suppl. 5/96 (1996) 53–58. No workshop has been located in north Italy. On the possibility of a manufacturing center at Augsburg, documented by deformed fragments of Salvius Gratus' bottles and waste: Rottloff (supra n. 33) 170–72. More on Salvius Gratus, infra n. 152.

[84] W.V. Harris ed., *The Inscribed Economy. Production and Distribution in the Roman Empire in the Light of* instrumentum domesticum (*JRA* Suppl. 6, Ann Arbor 1993); J.-J. Aubert, *Business Managers in Ancient Rome* (Leiden 1994).

[85] Stern 1995, 68–69 and 73–74.

[86] *P Oxy.*, vol. 45, no. 3265 and vol. 54, no. 3742, both quoted in full infra pp. 464, 465. In Rome some of the *collegia* may have acted as guilds for the benefit of their members: DeLaine 204.

[87] M. McClellan, "Recent Finds from Greece of First-Century A.D. Mold-Blown Glass," *JGS* 25 (1983) 71–78; Cool and Price 43, 227.

[88] D.B. Harden, "Romano-Syrian Glasses with Mould-blown Inscriptions," *JRS* 25 (1935) 163–86, esp. 164–65.

[89] W.V. Harris, "Roman Terracotta Lamps: The Organization of an Industry," *JRS* 70 (1980) 126–45.

[90] Aubert (supra n. 84) 302 cites only one stamp, from Asia Minor.

[91] Stern 1995, 69–72.

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pretation of these contracts is not always clear, but they do show an interesting variety in stipulations concerning the lease of workshop and storeroom space, equipment, and even raw materials such as clay and firewood. In one contract, dated 243, a potter-lessee named Aurelius Paesis undertook to deliver a set number of wine amphoras at a set time for which the landlord would pay a fixed price in money and kind. The duration of the contract was for two years. The potter brought his own assistants and had total control of the leased premises. Apparently, he was an independent craftsman, managing his own business and entering the contract in his own right.[92] No such contracts for glassworking have been identified, so we do not know if they existed or if they resembled potters' contracts.[93]

In the absence of evidence for the Roman period, a hoard of documents detailing economic and social conditions in the late 10th to early 13th centuries sheds light on the types of contracts and agreements glassblowers made among themselves. Known as the Geniza documents, they were recovered from the Geniza (religious archive) of a synagogue in Cairo.[94] In one document two glassblowers agree to blow glass together for a period of six-and-a-half months: a glassblower named Abu Sa'd provides 20 dinars, while his partner does not contribute any capital but receives a personal loan (from Abu Sa'd) of 10 dinars, on condition that Abu Sa'd will work only two "turns" a week, and his partner the rest.[95] In a second contract two other glassblowers agree to work together for the duration of one year: one partner provides 199 dinars, the other only 6, contributing also a small quantity (10 qintars, i.e., 1000 Fustat pounds or ca. 450 kg) of raw material.[96] They invested the 199 dinars in raw glass: 105 qintars of locally made glass and 108 qintars of imported red glass. A third contract mentions "a partnership in the manufacturing of glass vessels, which was done in a store of copperware" (!) (in Damascus). A fourth document describes a partnership between Jewish and Muslim craftsmen (silversmithing or glasswork): their tools were "common property, on condition that profits made on Fridays belonged to the Jews and those made on Saturdays accrued to the Moslims."

From these agreements it is clear that the glassblowers were owner-entrepreneurs, even if they could not provide cash capital. The contract featuring Abu Sa'd is the only one to mention the hiring of a skilled craftsman. The use of hired labor may have been more common in primary glassmaking. A fragmentary contract dated to the spring of 1057 describes an agreement between two partners and a laborer in Cairo, "all three being indiscriminately termed *zajjaj*, glassmakers. . . . The laborer undertook to work on the melting furnace for the duration of a year. . . . His remuneration would consist in 5 dirhems and lunch worth 1 dirhem on any day he worked. He would not work for anyone else during the period of the contract."[97] The laborer's wages were the common wage of the time, paid at the end of each day. The addition of a meal appears to be rooted in Roman practice. Goitein suggests that the stipulation that the man was not to work for anyone else indicated a tight labor market. Another explanation might be the owners' fear of disclosure of glassmaking recipes.

The agreements described in the Geniza documents show that great differences existed between the income (and presumably the social status) of individual glassblowers. The glassblower Abu Sa'd mentioned in the first of the agreements cited above was very successful. Two years later he contributed 400 dinars in cash to a partnership for making wine. At the other extreme stands his partner who needed a personal loan of 10 dinars to pay for his own contribution. He offered the title deeds to his house as security, but he entered the contract as an owner-partner. The enterprise itself must have been modest, since they had no more than 30 dinars to begin with. The two glassblowers mentioned in the second contract began with 205 dinars (199 + 6) and ca. 450 kg (10 qintars) of raw glass.

Diocletian's Price Edict

The single most important document recording the prices of glass in the Roman empire is Dio-

[92] Aubert (supra n. 84) 253–55.

[93] The Egyptian papyri are currently being analyzed for references to the glass industry; work in progress by Traianos Gagos and myself.

[94] Goitein 87–88; the contracts cited pp. 363–65, nos. 9, 19, 8, and 17 respectively.

[95] The Muslim gold coin *dinar* weighed 4.233 g. Two dinars "were regarded as monthly income sufficient for a lower middle class family . . . The dirhem was a coin of low silver content." Approximately 36–40 dirhems had the value of one dinar (Goitein 359–60).

[96] "The basic weight was the dirhem (not to be confused with the coin bearing the same name) weighing 3.125 g. The common pound of Fustat consisted of 144 dirhems (or 12 ounces of 12 dirhems), approximately 450 g, comparable to the present day U.S.A. pound . . . One hundred pounds made a qintar" (Goitein 360). The word was derived from *kentenarion* "one hundred pounds," which was the basic weight for glass in Roman Egypt. See infra 464–66 with discussion *P Oxy.* vol. 45, no. 3265 and *P Oxy.* vol. 54, no. 3742.

[97] Goitein 94. On the value of the dirhem, supra n. 95.

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cletian's Price Edict (hereafter PE). Issued in November/December 301, presumably at Alexandria but almost certainly prepared while the emperor was residing in Antioch, the PE lists prices for six types of glass.[98]

The declared purpose of the PE was to check inflation. The prices mentioned in the PE were maximum prices, not fixed prices. The preamble specifically encourages lower prices in places where goods were abundant. Originally composed to aid soldiers, the PE aimed to benefit the entire population of the Roman empire. The prices would have been particularly beneficial to groups living on a fixed income. State purchases for army and imperial court supplies seem to have been made at the listed prices.[99]

Because the PE was prepared in Antioch, the choice of items to be included in the list is thought to reflect, to some extent, Antiochene conditions. The Antiochene connection is of interest for glass studies because the city is not actually mentioned as a glass center in the Roman period,[100] although the general region was renowned for its glass, and glass was certainly being worked (or made?) in Antioch in the 12th century.[101] A new interpretation of the prices for architectural glass (see below) is consistent with the observation that the PE offers no positive proof "that western or even non-Antiochene conditions were taken into account."[102] The PE's maximum prices for glass are outlined in Table 1.[103]

Barag[104] argues that Alexandrian and Judaean do not refer to the origin of the glass but to generic types (qualities) of glass. He convincingly identifies Judaean glass with common bluish green glass, often called "natural colored glass" in modern glass literature. This is also indicated by the word *vir<i>dis*, "greenish."[105] The more expensive Alexandrian glass was colorless, i.e., intentionally decolorized. Barag shows that the geographic designations date from a period long before the PE, presumably from the first century, but certainly in the case of Judaean glass, before the year 135; in that year Hadrian officially abolished the province of Judaea. As a penalty for the Bar Kochba revolt of 132–135 he renamed the province Syria Palestina. The use of a geographical designation that had ceased to be meaningful at the time of the PE is known also from other goods.[106]

The prices for glass vary according to the stages of production. One may compare the prices for pairs of wooden wagon parts qualified by the terms *fabricatum* and *infabricatum*.[107] Raw glass and vessel glass were both sold by the pound, i.e., the Roman pound of 327.45 g.[108] The PE uses two words to indicate the weight: *libra* (Gk. *litra*), referring to raw glass, and *pondo* to vessel glass. The choice of the word probably reflects the reality of transactions: raw glass was sold in multiples of one pound (libra), whereas the merchant needed to use a balance with a weight (*pondus*) to calculate the price of a glass vessel. The pricing of glass vessels by weight rather than per piece may well have been common practice in the late Roman empire, especially if the addition of *levis* "smooth," in lines 3 and 4 indicates that the vessels were not decorated by engraving or otherwise.[109]

Selling glass vessels by weight can be compared to basing the price of a pottery container on its capacity.[110] Both types of prices are objective: they reflect

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[98] Giacchero. The Latin version has been reedited by J.M. Reynolds in C. Roueché, *Aphrodisias in Late Antiquity* (*JRS* Monograph 5, 1989) 265–318. For a recent discussion of date, place of issue, intended audience, choice of items to be included, prices, and general background of the PE: S. Corcoran, *The Empire of the Tetrarchs. Imperial Pronouncements and Government A.D. 284–324* (Oxford 1996) 205–33, reviewed by W. Turpin, *JRA* 11 (1998) 652–56.

[99] Turpin (supra n. 98) 655 with n. 11.

[100] On the glassblower Paulinos who identified himself as an Antiochean, infra n. 155.

[101] Benjamin of Tudela: "Ten Jews dwell here, engaged in glassmaking . . .," cited by C.J. Lamm, *Mittelalterliche Gläser und Steinarbeiten aus dem Nahen Osten* 1: *Text* (Berlin 1930) 491, no. 46.

[102] Corcoran (supra n. 98) 220–23; the citation is from p. 223.

[103] PE 16.1–6; first published by K.T. Erim and J. Reynolds, "The Aphrodisias Copy of Diocletian's PE on Maximum Prices," *JRS* 63 (1973) 99–110, esp. 103, 108, 109, column III, lines 35–39. The Latin text here follows Reynolds (supra n. 98) 281. See also D. Barag, "Recent Important Epigraphic Discoveries Related to the History of Glassmaking in the Roman Period," *AnnAIHV* 10, 1985 (Amsterdam 1987) 109–16, esp. 113–16. The Greek text is from Giacchero 171.

[104] Barag (supra n. 103) 113–14.

[105] Erim and Reynolds (supra n. 103) published the text as S<ub>VIR<i>DIS and commented "probably a mistake for *viridis* or *subviridis*" (103).

[106] Corcoran (supra n. 98) 222 quotes as an example "dalmatics."

[107] PE 15.1–29; see also Corcoran (supra n. 98) 225.

[108] Giacchero 117. D.K. Charlesworth, in Erim and Reynolds (supra n. 103) 109 saw "no obvious rationale" in the use of different words to indicate the same weight of one pound.

[109] So already Charlesworth (supra n. 108) 109. One may compare the use of Greek *leia* for smooth-walled metal and glass vessels: E.M. Stern, "Glass in Athenian Temple Treasures," *JGS* 41 (1999).

[110] PE 15.101; Erim and Reynolds (supra n. 103) 108, commentary to line 33 *cetera vascula pro ratione [capacitatis?]* "other clay vessels according to their capacity."

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Table 1. Diocletian's Price Edict (PE) 16.1–9 in Latin and Greek, with Translation of Lines 1–6

16.1	DE VITRO		16, 1	GREEK TEXT	
1a	Vitri Alexandrini libra una	[Ж] viginti quattuor	1α		
2	[Vitri I]udaicis virdis libra una	[Ж t]redecim	2		
3	[Vitri Ale]xandrini in calicibus et vasis levibus in pondo uno	Ж triginta	3		
4	Vitri Iudaici in calicibus et vasis levibus in po(ndo) unum	Ж viginti [i	4		
5	Speclaris optimi libra una	Ж octo	5	[- - - - - - - - - λ(ίτρα)] α′	Ж η′
6	Secundi libra una	Ж sex	6	[- - - - - - - -] λ(ίτρα) α′ ·	Ж ς′
7	[DE - - - - ? - - -] ḄṲṢ		7	[ΠΕΡΙ - - - - - -]	
7a	[- - ? - - lib(ra)] una	Ж qua[draginta]	7α	[- - - - - - - -]ου λ(ίτρα)] α′	Ж μ′
8	[. . . c.10 . . . coloris? li] b (ra) una	Ж tr[iginta]	8	[- - - - - - - -] χρώματ(ος) λ(ίτρα) α′	Ж λ′
9	[. . . c.10 . . . coloris? l] ib (ra) una	Ж vig[inti]	9	[- - - - - - - -] χρώμ(ατος) λ(ίτρα) α′	Ж κ′
	FOR GLASS				
1a	Alexandrian glass one pound	denarii 24			
2	Judaean greenish glass one pound	denarii 13			
3	Alexandrian glass cups and smooth vessels one pound	denarii 30			
4	Judaean glass cups and smooth vessels one pound	denarii 20			
5	Window glass, best (quality) one pound	denarii 8			
6	[Window glass] second (quality) one pound	denarii 6			

See p. 466 for translation and discussion of lines 7–9

the amount of raw material and labor in making the object rather than its degree of aesthetic perfection. The rationale is utilitarian: functionality is the determining factor. The same rationale still prevails in Afghanistan.[111] It is not clear how generally glass vessels were sold by weight in antiquity[112] or when this practice began. Luxury glass and decorated vessels were always sold per piece.[113]

There are two ways to evaluate whether the price of vessel glass was expensive or inexpensive. One is by comparing the prices of different types of goods; the other is by trying to relate the price to the cost of living and prevailing wages.

In the PE, the price of a pottery container with a capacity of two *sextarii* (1.094 lt) was two denarii.[114] Although a capacity of two sextarii was small for a clay vessel, it was relatively large for a glass vessel. Barrel-shaped "Frontinus" bottles with a capacity of two or one-and-a-half sextarii had an average weight of one pound (fig. 26); late Roman eastern Mediterranean spherical bottles of comparable capacity weighed approximately one to two Roman pounds. Made of natural bluish-green glass, the bottles weighing near one pound would have cost approximately 20 denarii, the two-pounders over 40 denarii—that is 10–20 times as much as a comparable pottery container.

The PE (7.1–23) lists maximum wages for several occupations. The minimum daily wage for unskilled labor was 25 denarii plus meals worth ca. 5–10 denarii, a total of 7,700 denarii over a year of 220 days or 10,150 denarii over a year of 290 days.[115] Skilled laborers earned 50–60 denarii plus meals. The average weight of a late Roman glass vessel is approximately 150–350 g. At the PE's prices of 30 and 20 denarii per pound, depending on whether the vessel was made of Alexandrian colorless or Judaean bluish green, 25 denarii—the equivalent of one daily wage of an unskilled laborer—would have sufficed to buy

[111] Reut (supra n. 40) 107; Taborelli 1997 (supra n. 40) 160.

[112] Barag (supra n. 103) 116 quotes several examples dating from the 12th to the 20th century of glass sold by weight.

[113] Infra p. 61.

[114] PE 15.98. The *sextarius* was 0.547 liter, corresponding to one sixteenth of a *modius*: Giacchero 117. G. Sennequier, *Verrerie d'époque romaine. Musée des Antiquités de Rouen*, Collections des musées départementaux de Seine Maritime (Rouen 1985) 169 notes that Frontinus bottles were made with standard sizes of 3 *sextarii* (1.62 lt); 2 *sextarii* (1.078 lt) (here fig. 26); 1.5 *sextarius* (0.80 lt); 0.5 *sextarius* (or 6 *cyathi*, 0.27 lt); and 1.5 *cyathus* (0.068 lt).

[115] On the relative value of a worker's meal: DeLaine 210; see supra p. 460 with n. 97 for medieval Cairo.

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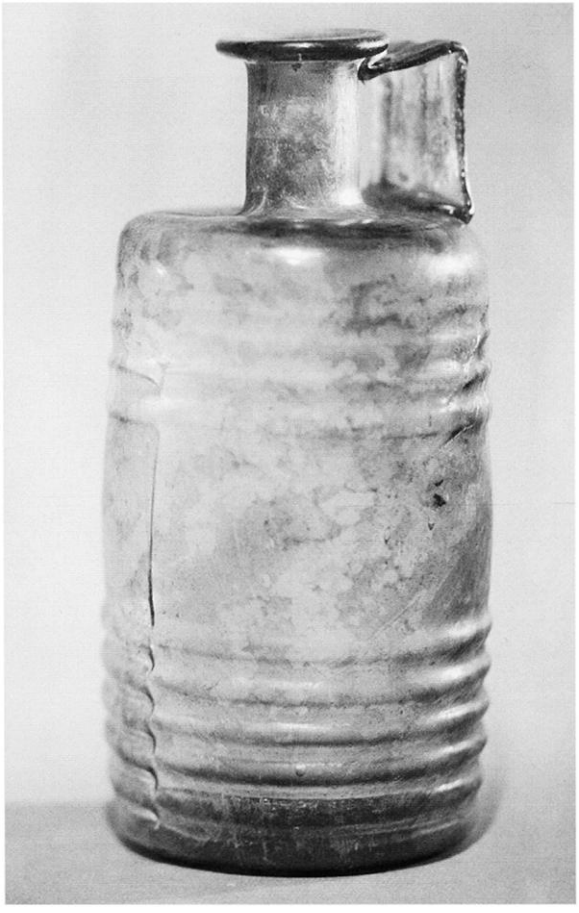

Fig. 26. Frontinus bottle. H. 22.4 cm; Dm. base 8.5 cm; Weight 377 g. Inscribed FROTINIANA. Annular pontil scar. Late first to early second century. Made in northwest Europe. (Courtesy Toledo Museum of Art, no 1948.220. Purchased with funds from the Libbey Endowment, gift of Edward Drummond Libbey.)

one or two average size vessels of Judaean glass or one average size vessel of Alexandrian glass.

Another way to relate prices to the cost of living uses the price of wheat or its equivalent. The PE set the maximum price of one *kastrensis modius* "army *modius*" (hereafter KM) of wheat at 100 denarii.[116] The minimum net consumption per person per year has been estimated at the equivalent of 250 kg wheat. At a weight of 6.55 kg per modius[117] this works out to approximately 38.168 modii or 19.084 KM per year[118] or, in the PE's prices, the equivalent of just over 1900 denarii per year (1908.4 denarii, to be precise).

It is interesting to note that the PE's prices for glass vessels are much lower than the prices in medieval Cairo. A Geniza document dated January 1104 mentions 18 empty glass vessels with a total value of two dinars, a price considered to have been the equivalent of a lower middle-class family's monthly income.[119] The price is even higher when one takes into account that the 18 vessels were listed among items for sale in a legume shop, a context suggesting they were utilitarian items made of natural bluish-green glass. As will be shown below, the Geniza prices were probably more realistic.

Whereas the prices of finished vessels were important for the glassblower/retailer and for the general public, the glassblower's primary concern was with the prices of raw glass, because he or she needed a certain amount of it to set up business. Other requirements included work and storage space, equipment (furnace), fuel, and tools. Any or all of these items, including the raw material, might in theory be leased, as several potters' contracts from Roman Egypt suggest (see above). Most glassblowers would probably have preferred to work with their own tools, because blowpipes and hand-held tools tend to adapt their shape to fit into the user's hand (and mouth), and also because one's own tools are treated with the most care.

The contracts mentioned in the Geniza documents indicate that the amount of raw glass involved in setting up shop could vary considerably. The bare minimum would probably have been near 10 qintars (ca. 450 kg), the amount contributed by a glassblower mentioned in one of the Geniza documents.[120] At the PE's prices, this would translate into an investment of 33,720 denarii for 1405 pounds of Alexandrian glass, or 18,265 denarii for the same quantity of Judaean glass. In either scenario, the investment in raw glass was a huge expense. Taking into account the inevitable waste of glass during blowing (ca. 40–45%),[121] 450 kg raw glass sufficed to blow approximately 1080 vessels with an average weight of 250 g,

[116] PE 1.1a. Wheat was measured by volume. One modius was 8.754 lt; the KM was twice as much: 17.51 lt: Giacchero 117.

[117] K. Hopkins, "Taxes and Trade in the Roman Empire," *JRS* 70 (1980) 101–25, esp. 118–19.

[118] DeLaine 220 quotes a normal monthly rate of five modii per recipient.

[119] Goitein 151: price of 18 vessels; supra n. 95: monthly income.

[120] Goitein 365, no. 19.

[121] Henein (supra n. 40) 20 states that 1250 g of broken glass yields 1000 g of molten glass, a loss of 20%; during blowing, waste from material remaining on pipe and punty and sticking to crucible accounts for an additional loss of ca. 20–25%.

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approximately 10–11 days worth of blowing. With luck some of the first glass vessels might be sold by the time raw glass ran low, allowing the glassblower to buy new supplies or take out a loan.

The PE's maximum prices would have made it very difficult for most glassblowers to earn a living. Lactantius's statement (*De mort. pers.* 7.6) that the PE "drove goods off the market (evidently because its price-ceiling was too low to allow any profit)"[122] may well have been true for utilitarian vessel glass. The glassblower would have had to work below the cost of production. The total weight of the 1080 vessels that could be blown from 450 kg raw glass would have been ca. 270 kg, or 825 Roman pounds. The PE allows a maximum sales price of 30 denarii per pound for Alexandrian glass vessels, which translates into 24,750 denarii for the lot—significantly short of the 33,720 denarii necessary to buy 450 kg of raw glass. The maximum sales price for the same amount of vessels made of Judaean glass was 16,500 denarii, again less than the cost of raw glass. Under these circumstances every glassblower's top priority must have been to cut back on waste and recycle as much as possible.

The last type of glass mentioned in the PE is *spec<u>laris*, probably "window glass," certainly architectural glass (16.5–6). Its low price is an indication that this was a low quality glass. It has been suggested that the inclusion of window glass in the PE was more relevant for the western half of the Roman empire than for the eastern Mediterranean, because in the third century glazed windows were not widely used and especially not in the East.[123] Most documentation of ancient glazing has been concentrated on Italy and the West. However, there is increasing evidence for extensive use of window glass in the eastern Mediterranean long before the Byzantine period. The windows of the South Baths at Bosra are coeval with the original construction of the building in the second century.[124] Window glass was an important item in all Roman Bath buildings: it was necessary to keep in the heat while admitting light, especially in the caldaria. The use of glass for this purpose is mentioned by several first-century Roman authors.[125]

Two early fourth-century papyri from Oxyrhynchus suggest that window glass was also common in Egypt. The specificity of these documents requires a short discussion in spite of this paper's focus on vessel glass. In a declaration of prices dated 26 November 317, a member of the glassworkers' guild at Oxyrhynchus cites a price of four talents per hundred pounds of glass:[126]

> To Valerius Ammonianus alias Gerontius, *curator* of the Oxyrhynchite, from the guild of the glassworkers of the illustrious and most illustrious city of the Oxyrhynchites, through me Aurelius Areion, son of . . . In accordance with orders, at my own risk I declare the price entered below for the goods which I handle, and I swear the divine oath that I have been deceitful in nothing. As follows:
> Glass, by weight 100 pounds talents four.
> In the consulship of Ovinius Gallicanus and Caesonius Bassus, *viri clarissimi*. Hathyr 30. I Aurelius Areion, have presented this, making my declaration as aforesaid.—I Aurelius Pathermouthis, wrote on his behalf as he is illiterate.

Previous publications associate the price of four talents with the PE's price of 24 denarii per pound of Alexandrian raw glass, the most expensive raw glass for vessels. The declaration does not state the purpose of the glass, but the price appears rather low for vessel glass. Four talents per hundred pounds of glass translates into 6,000 denarii,[127] or 60 denarii per pound. If this was the price of Alexandrian raw glass in 317, it suggests an average annual compound inflation of 5.89% in the 16 years following the PE.[128] Inflation rates fluctuated and varied according to commodity. A low inflation rate has been noted for a few commodities, but 5.89% is very low in comparison to the average inflation of 13.91% between 301 and 359, and 18.97% between 310/11 and 359.[129] If the annual inflation percentage of glass was the same as the average annual inflation, the declaration of 317 should refer to window glass,

[122] R. Duncan-Jones, *The Economy of the Roman Empire. Quantitative Studies* (Cambridge 1974) 367.

[123] Barag (supra n. 103) 116, following D.K. Charlesworth's hypothesis in Erim and Reynolds (supra n. 103) 109.

[124] H. Broise, "Vitrages et volets des fenêtres thermales à l'époque impériale," in *Les Thermes Romains, Actes de la table ronde organizée par l'Ecole Française de Rome, Nov. 1988* (Collection de l'Ecole Française de Rome 42, 1991) 61–78, esp. 68–74.

[125] Broise (supra n. 124) 61.

[126] *P Oxy.*, vol. 54, no. 3742.

[127] After Diocletian's reform, the talent in Egypt equaled 1,500 denarii: R.S. Bagnall, *Currency and Inflation in Fourth Century Egypt* (Bulletin of the American Society of Papyrologists Suppl. 5, 1985) 16–17.

[128] *P Oxy.* vol. 54, p. 238.

[129] *P Oxy.* vol. 54, pp. 233; Corcoran (supra n. 98) 225–26 rounds off these figures at 14% and 19% respectively. I thank D. Black, University of Toledo Department of Economics, for calculating inflation rates.

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which the PE priced at 8 and 6 denarii respectively for first and second quality. The price of 60 denarii per pound in 317 is consistent with an annual inflation rate of 13.42% for first quality window glass and a rate of 15.48% for second quality window glass.

A second declaration by the same glassworkers' guild at Oxyrhynchus, dated June/July 326, specifies the use of 6000 pounds of glass in the construction of the public bath:[130]

> In the consulship of our masters Constantinus Augustus for the seventh time and Constantius the most illustrious Caesar for the first time. To Flavius Leucadius *logistes* of the Oxyrhynchite nome from the guild of glassworkers of the glorious and most glorious city of the Oxyrhynchites through me, Aurelius Zoilus. . . . In response to your demand for an account of all the matters affecting our profession relating to the service of fitting out the warm baths in the public bath of the city, I have perforce drawn it up and submit it in order that your grace may be able to know. It is: for the work needed on the warm baths, x hundred pounds; for the work needed on the gymnasium, x hundred pounds; at a rate of 22 talents per hundred pounds. Total 6000 pounds, total 1320 talents. Which we accordingly report. In the aforementioned consulship, Epeiph. . . . I, Aurelius Zoilus, have presented this as set out above.

The glass used in the public baths in 326 can hardly be anything other than architectural glass. Previous publications have combined the prices mentioned in the two papyri and interpreted them as evidence for an increase of 450% in the price of glass.[131] This sounds very high for a period of just eight-and-a-half years, but it translates into an annual inflation of 20.22% for the years 317–326. Although the rate may thus seem acceptable,[132] it cannot be used. The glassworkers' declaration of 326 states explicitly that the 22 talents per pound include the cost of "fitting" the glass. I propose to establish the price of the glass itself by basing it on the average annual inflation rate for the period 301–326.

Two average inflation rates for the first half of the fourth century have been calculated; the lower rate of ca. 14% includes the years 301–310/11, the higher rate of ca. 19% does not (see above). Taking into account that the two glass declarations belong to the first quarter of the century, and noting that the average increase in the value of the gold solidus was 16.33% in the years 301–340, I use a hypothetical inflation rate of 16% for the years 301–326. Even if it is not accurate, it gives an idea of the price range. With an inflation rate of 16%, second quality window glass priced at 6 denarii per pound in 301 would have cost about 245.25 denarii per pound in 326. This translates into 16.35 talents per 100 pounds of glass. If this is an acceptable hypothesis, the remaining 5.65 talents per 100 pound, about one quarter of the price, represented labor and other costs.

The total invoice of the glassworkers' guild was 1320 talents. Of this sum 339 talents, or 508,500 denarii, were left to cover the cost of wages, scaffolding, transport to the building site, and other construction costs. Six thousand pounds of glass would have sufficed for approximately 242.37 m^2 of window panes.[133] No data are available for calculating the cost of glazing, but there are indications for the cost of placing mosaic cubes. Window panes were much larger than mosaic cubes, but—unlike the cubes—each individual pane must be framed in wood, plaster, or metal. The construction of the frame itself might be complicated by provisions for opening and closing the window for ventilation.[134] In the absence of data on glazing, I therefore tentatively substitute the wages that would have been needed to fit the baths at Oxyrhynchus with 6000 pounds of decorative glass mosaics instead of with windows.

Mosaic cubes were made from flat glass "cakes" having the thickness of the cubes (ca. 0.7 cm). The cake was scored and broken up into tesserae.[135] Colored glass could be imported in the form of cakes, but glassworkers may have also prepared the cakes themselves. The process was simple and involved little labor apart from gathering and transporting fuel. The natural surface tension of glass causes any chunk of raw glass to flatten out into a puddle when melted that, upon cooling, stiffens into a cake or disk of 0.7

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[130] *P Oxy.*, vol. 45, no. 3265.

[131] *P Oxy.* vol. 54, no. 3742, commentary to line 13. Bagnall (supra n. 127) 69 does not calculate the rate of inflation but lists the prices for glass at 4 and 22 talents as though they refer to the same item.

[132] The commentary to *P Oxy.* vol. 54, no. 3742 (supra n. 131) states that the average annual inflation was 22.2%, but it does not specify the time period.

[133] Calculation based on the fact that 8390 cm^2 of cast glass window panes weighed 6.8 kg. For this and the methods of producing window panes, see J. Price: "Glass," in R.P.J. Jackson and T.W. Potter, *Excavations at Stonea, Cambridgeshire 1980–85* (London 1996) 397–409, esp. 396–97. Blown window panes, which became common in Britain in the late third and fourth centuries, would probably have been slightly thinner and covered a larger surface. On the possibility of primary glassmaking (for window glass?) in northern Britain: C.M. Jackson et al., "The Manufacture of Glass in Roman York," *JGS* 40 (1998) 55–61.

[134] Broise (supra n. 124). One window usually consisted of several panes.

[135] S.M. Goldstein, "Glass Fragments from Tell Hesban," *Andrews University Seminary Studies* 14.1 (1976) 127–32, esp. 129.

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to 0.8 cm thickness.[136] Numerous broken cakes of glass in various colors (several tints of bluish-green, gray, black, and red) were found at Gerasa, with a total weight of 45–50 kg. Roughly circular in shape, some measured up to 40 cm in diameter; the average thickness was 3–4 mm.[137]

Six thousand pounds of glass would have sufficed to cover ca. 100–109 m^2 of wall and vaults in the public bath at Oxyrhynchus, without counting the space between the cubes (ca. 20%). At ca. 15,000 cubes to the square meter, DeLaine calculated that fitting took ca. 2.8 days per square meter.[138] This means that the glassworkers at Oxyrhynchus needed at least 280 man-days to complete the job. At an average annual increase of 16%, the PE's daily wage of 25 denarii for one unskilled laborer (plus food worth 5–10 denarii in kind) would have risen to somewhere between 1,216.32 and 1,420.69 denarii (for wages worth 30 and 35 denarii respectively). Two hundred eighty days of labor cost the guild 240,570–401,793 denarii. This seems possible with 508,500 denarii available for wages, plus the cost of scaffolding, fuel, supervision, and transport.

The above calculations show that window glass fits the specifications of both papyri. An alternative possibility is that the glass used in the construction of the baths was not for window glass but wall mosaics. Glass mosaic cubes were a common form of decoration in public buildings. J. DeLaine calculated that 16,900 m^2 of glass mosaic decorated the walls and vaults of Caracalla's baths at Rome.[139] The above calculations have already shown that 339 talents would have sufficed to fit glass mosaic cubes.

For the Baths of Caracalla in Rome, which were decorated with figural mosaic designs, DeLaine based her calculations on the price of Alexandrian raw glass because she reasoned that colored glass would have been more expensive than natural bluish-green Judaean glass. Unless glass mosaic cubes were as inexpensive as window glass, which seems improbable, the price of 22 talents, which included fitting, cannot apply to mosaics. I suggest that the two declarations of the Oxyrhynchus glassworkers' guild in 317 and 326 both refer to window glass.

PE 16.7–9

An entry for glass mosaic cubes is missing in the PE's section on glass. I would like to suggest that it was contained in PE chapter 16, lines 7–9, given in Table 1. The main reason for suggesting that this section refers to glass mosaic cubes (or the cakes for making them) is the occurrence of the word "colored" in lines 8 and 9. The word itself is not preserved in the Latin version but appears in the Greek edition of the PE: *chromatos* "(of) color." Glass is one of the few materials where color is a significant factor in determining the price. Today's prices vary between U.S. $18.99 and $70.85 per kg, depending on the coloring agent.[140]

The number of letters missing in line 7, the section title, is unknown. J. Reynolds originally interpreted the last letters of the last word in the title as ARIS, which is also the text given by Giacchero. If that reading is correct, the missing word was perhaps related to MUSEARIUS, PE chapter 7, line 6, with reference to the wage of a *musearius*, a fitter of glass mosaics. In her 1989 reedition of the text Reynolds proposes to read BUS at the end of the heading, which she tentatively interprets as *coloribus* "colors."[141] The Greek copy of the PE preserves in line 7a a masculine genitive ending in *ou*, which is consistent with a lost word *chrysou* "of gold (leaf)" glass.[142] If my hypothesis is correct, that this section is about glass for mosaics, the three maximum prices of 40, 30, and 20 denarii respectively could refer to gold leaf, colored, and natural bluish-green cubes (or the cakes for making them).

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[136] Stern (supra n. 43) 25–29; Stern 1994, 66–67. Von Saldern (supra n. 9) 97, no. 729, pl. 17 illustrates a fragment of a blue cake for making cubes. On Roman imperial trade in cakes of colored glass, infra n. 213.

[137] P.V.C. Baur, "The Glassware," in C.H. Kraeling ed., *Gerasa, City of the Decapolis* (New Haven 1938) 505–46, esp. 517–18.

[138] DeLaine 180–82.

[139] DeLaine 180; large numbers of glass mosaic cubes of the fifth to sixth century were excavated at Sardis: von Saldern (supra n. 9) 92–94, pl. 17.

[140] On current prices for raw glass: E.M. Stern, "Glass and Rock Crystal. A Multifaceted Relationship," *JRA* 10 (1997) 193 with n. 5.

[141] This section is part of the Aphrodisias copy: Erim and Reynolds (supra n. 103). Reynolds 1989 (supra n. 98) was brought to my attention by the author who plans to have another look at the stone in the summer of 1999. In the Aphrodisias copy, the section on pens and ink (four lines) are cut immediately after the section on glass; the lines numbered 15.7–9 by Giacchero appear at the top of the next column. The coverage of the PE was not complete, but "glass cubes for wall mosaics are a very attractive idea, and while logic does not seem to have been an obviously guiding factor in the organization of the edict, there could be some logic in the progression Glass to Glass Mosaic Cubes to Ivory and Tortoise Shell" (J. Reynolds, personal communication January 1999).

[142] On sandwiched gold leaf tesserae see von Saldern (supra n. 9) 93; a late Roman or early Byzantine cake of sandwiched gold leaf for making mosaic cubes was excavated at Heshbon in Israel: Goldstein (supra n. 135) 129 and pl. XI:B, bottom row.

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COMMERCE AND TRADE

The chief interest of the glass industry for economic historians lies in the fact that its products belong to several categories—raw materials, household and utility ware, and luxury items including fine tableware—each of which can reflect the prosperity of different groups of the population. The aim of this section is to discuss some of the evidence for commerce and trade as it relates specifically to the glass industry, not to present an economic distribution model for Roman glass. The emphasis is on distribution patterns and means of transportation. Vessel glass, for example, was made in all parts of the Roman empire, but there is literary and archaeological evidence that it was also traded by water and by land, both within and beyond the borders of the empire.

Just as the glass industry was divided into two separate branches, one concerned with making the raw material, the other with working it into objects, so also commerce in glass was twofold. Workshops needed raw glass, and finished vessels needed to reach customers. There was probably also a limited trade in blanks and half products for engraving, cutting, and painting. Recycling, a fourth commercial outlet, would engage merchants from the smallest peddler to large-scale enterprises involving shipments of tons of cullet (broken glass vessels).

Whereas long distance trade in fine tablewares, raw glass, and cullet could be economically profitable (see below), most unguentaria, ordinary household containers, tableware for daily use, and funerary urns were destined for local and regional markets. Variations in the finishing of individual objects and the prevalence of specific shapes in one region are evidence for increasing regionalization of production beginning in the second half of the first century.[143]

Flavian poets mention peddlers hawking sulphur for broken glass. Martial (*Epigr.* 1.41) disparagingly compares someone to a *transtiberinus ambulator/qui pallentia sulpurata fractis/permutat vitreis* "tramping hawker from beyond the Tiber who exchanges pale sulphur matches for broken glass."[144] Itinerant merchants and peddlers probably included some glass among the wares they brought to outlying villages and they may have brought back fragments of broken glass vessels.

Distribution maps provide an interesting basis for reconstructing patterns of ancient trade. Tableware and most other glass vessels were sold empty, so their trade patterns reflect commerce in glass, but certain types of glass bottles appear to have been sold filled with specialized contents, implying cooperation between the manufacturer of the content and the glassblower. For example, unguentaria shaped like birds and spheres were filled with cosmetic powders and fire-closed at the tip.[145] The distribution of such vessels reflects the commerce of their contents.

Inscribed Bottles: Evidence for Glass Trade?

Several classes of larger storage and/or transport glass bottles carry mold-blown inscriptions. Mercury bottles, for example (fig. 27, Isings Form 84), were named after the base molding that often includes a representation of Mercury. Mold-blown barrel-shaped bottles with one or two handles were also known as Frontinus bottles (Isings Forms 89 and 128, fig. 26) because of the frequency with which that name appears in the base molding. Many prismatic bottles (usually square, Isings Form 50), have base moldings with inscriptions and/or geometric designs on the bottom. The greatest interpretive dilemma associated with these bottles is whether the base moldings refer to the glassblower or to the producer of the contents.[146]

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[143] Price (supra n. 8) 30–39; Cool and Price 225–27.

[144] Compare Juv. 5.48 and Stat. *Silv.* 1.6.74. See C. Isings, "Exchanged for Sulphur," in *Festoen Opgedragen aan A.N. Zadoks-Josephus Jitta bij haar zeventigste verjaardag* (Scripta Archaeologica Groningana 6, Groningen n.d., ca. 1976) 353–56.

[145] Isings Forms 10 and 11. For recent analyses confirming that the content was colored powder: L.A. Scatozza Höricht et al., "Prime osservazioni ed analisi sul contenuto di alcuni recipienti in vetro rinvenuti nell' area archeologica di Pompei," in L. Franchi dell' Orto ed., *Ercolano 1738–1988. 250 anni di ricerca archeologica, Atti del convegno internazionale Ravello-Ercolano-Napoli-Pompei 1988* (Rome 1993) 557; J. Perez-Arantegui et al., "Analysis of the Products Contained in Two Roman Glass Unguentaria from the Colony of Celsa (Spain)," *JAS* 23 (1996) 649–55. C. Maccabruni, *I vetri romani dei Musei Civici di Pavia* (Pavia 1983) 108, n. 9, notes that an intact glass bird in Turin contained a rose-scented liquid. On birds, most recently: G.M. Facchini in *Vetro e vetri* (supra n. 11) 131–36.

[146] M. Sternini, "I vetri," in Harris (supra n. 84) 431–59 gives a useful survey of all classes of inscribed glass vessels. On Mercury bottles: Stern (supra n. 76) 64–72, no. 18; G. M. Facchini et al., "Studio di una forma vitrea di età romana: La Merkurflasche," *Postumia* 6.6 (1995) 150–73; M. Sternini et al., "Unguentari in vetro con bollo nelle collezioni del Museo Nazionale Romano," *Annali della Facoltà di Lettere e Filosofia* 17 (Università di Siena 1997) 55–100; G.M. Facchini in *Vetro e vetri* (supra n. 11) 139–46. On Frontinus bottles: Sennequier (supra n. 114) 169–82; Cool and Price 204–206. On prismatic bottles: Sternini 1993, 88–93: group III; Cool and Price 183–84 (square bottles 179–99).

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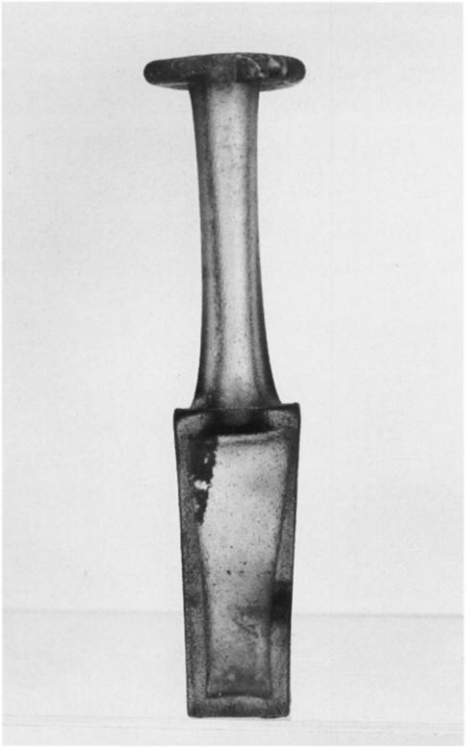

Fig. 27. Mercury bottle. H. 20.5 cm; wt. 243.8 g. Inscribed GFHI. No pontil scar. Second century. Made in Italy or northwest Europe. (Courtesy Toledo Museum of Art, no. 1987.216. Gift of Rabi R. Soleimani.)

Most prismatic bottles with base moldings are from findspots in the western half of the Roman empire. Their production technique appears to be one characteristic of the West: they were blown in smooth-walled molds, which made it possible to speed up the manufacturing process for creating containers with standardized capacity. This method for improving (economizing) the production of purely utilitarian vessels was very rare in the eastern Mediterranean.[147] The bottom section of the mold, carrying the base molding with the name, had four slots, one along each edge, for inserting panels that made up the walls. The curious construction of the mold with interchangeable parts would, in theory, have enabled one glassblower or one workshop to produce bottles with different base moldings for several commissioning parties, although there is no proof for this practice.

The base moldings of Sentia Secunda include an abbreviation VITR[a (or vitrearia)] for "glass" (or "glassworker"), and the word FECIT "made it" (figs. 23–25).[148] The occurrence of the word *fecit* makes it obvious that these moldings refer to the producer of the bottles; their findspots reflect overland trade in glass. Sentia Secunda's workshop was in Aquileia; the bottles were excavated in Linz, Austria. However, most moldings on square bottles do not include the word *fecit*.

The square bottles carrying the name of Salvius Gratus—without the addition of *fecit*—may serve to illustrate the problem of inscribed glass bottles. Bottles featuring his name in the base molding are common in north Italy and southern Germany. A ship that sank six miles from Grado (near Aquileia) with a mixed cargo of amphoras, glass (mostly cullet), and other goods included several fragments of bottles marked C Salvius Gratus, which may or may not have been cullet at the time of their sea passage.[149] If Salvius Gratus was a glassblower, the findspots are evidence of overland trade and short distance trade by ship (either with the bottles or with their shards). The findspots might even indicate the existence of a branch glass workshop at Augst.[150] On the other hand, if the base moldings refer to the contents, new bottles were not representative of trade in glass but trade in whatever filled Salvius Gratus's bottles.

Archaeological evidence suggests that the absence of a maker's identification does not of itself mean that the name seen in a base molding refers to the contents. In a shop at Herculaneum, an order of glass vessels still enclosed in packing materials included an empty square bottle with the name of P. Gessius Ampliatus in the base molding, a find circumstance that implies this square bottle was sold empty; in other words, this signature without the addition of *fecit* referred to the glass shop, not to the contents.[151]

In other respects, the problems regarding the interpretation of the names and the form in which

[147] Stern (in prep.). On the technique: V. Seitter, "Bemerkungen zur Herstellung von formgeblasenen römischen Gläsern mit Bodenmarken," *ArchKorrBl* 21 (1991) 527–33. Molds for square bottles have been excavated at Augst and Saintes: Rütti 163–64, fig. 103, pl. 218: 05 and 06; Hochuli-Gysel 1991 (supra n. 8), 85–87, figs. 5–7: six marble panels blackened through use, the panels themselves were reused revetment slabs. The mold published by F. Fremersdorf, "Die Anfänge der römischen Glashütten Kölns," *KölnJb* 8 (1965/66) 24–43, esp. 29 and fig. 2:9 is now thought to be "from the base of a pottery version of a square bottle": Cool and Price 180.

[148] On Sentia Secunda (supra n. 68).

[149] A.J. Parker, *Ancient Shipwrecks of the Mediterranean & the Roman Provinces* (BAR International Series 580, Oxford 1992) 197, no. 464, dated ca. 200; on the overland routes for bottles marked by Salvius Gratus: Roffia 1981 (supra n. 83).

[150] Rottloff (supra n. 33) 170–72. On the possibility of branch workshops producing bottles marked by Salvius Gratus: supra p. 459 with n. 83.

[151] A. de Franciscis, "Vetri antichi scoperati ad Ercolano," *JGS* 5 (1963) 137–39; on the gens Gessia and its connections with Campania: Scatozza Höricht 1991 (supra n. 11) 76–79. More on this shop: infra p. 471 with n. 174.

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they appear are similar to those encountered in pottery stamps. No agreement appears to exist on whether the latter refer to the owner's social status and/or should be interpreted as documents of business relationships.[152] The names on the glass bottles are usually Latin, but some inscriptions are in Greek.[153] The grammatical form of the name varies, appearing either in the nominative or in the genitive, possibly implying a different relationship with regard to production, such as the nominative (Sentia Secunda) for a master glassblower/owner and the genitive for a workshop product "of so-and-so." Other differences regard the convention of Latin names that can take the form of a freedman's name or of a Roman citizen. Two *tria nomina* stamps, each consisting of three initials that were sometimes combined on one bottle, may indicate persons playing the "composite role of producer-refiner-dealer of the valuable contents."[154]

In addition, there are some names that add a toponymic like "the Antiocheian" or "of/from Chios."[155] Whereas Sentia Secunda used the old-fashioned locative case to indicate that her workshop was at Aquileia, a toponymic can refer either to the location of a workshop or to the origin of an artist or artisan working far from home.

Goods (scents?) packaged and sold in glass containers with imperial administrative inscriptions in relief impressed on the underside were a special case; all aspects of production, packaging, and distribution were in the hands of the emperor. The inscriptions often include words such as VECTIGAL, PATRIMONIUM etc.; others include monetary stamps.[156] Most of these bottles have been found in Italy and the western part of the Roman empire; they have not yet been reported from the eastern Mediterranean. It is therefore of interest that the coin used to create the stamp of one bottle found in north Italy has been identified as minted by the Koinon Bithynia (128/129).[157] The wide-bodied unguent bottle (also known as candlestick unguentarium) that became fashionable in the second half of the first century might actually have been designed specifically to create space for this type of administrative inscription.[158] However, its exact purpose remains unclear. The fact that relatively few bottles are inscribed suggests that the inscription was not meant to guarantee the quality of the contents at the retail level. It is still unclear at which point in production, packaging, or distribution the inscription played a role and for whom it was destined, especially since wooden labels might be attached to the bottles to identify groups or "batches" of vessels.[159]

Retail

The excavations of the cities buried by Vesuvius's eruption provide fascinating opportunities to compare the number of silver, glass, ceramic, and bronze vessels in use at one moment in time. In these finds glass vessels outnumbered thin-walled pottery by as many as two or three times, a proportion strongly suggesting that glass had largely replaced thin-walled pottery as common tableware.[160] The glass vessels available for sale came from an astonishing range of locations in the West and East, suggesting intensive

[152] On the nomenclature in pottery stamps: Aubert (supra n. 84) 284–95. In the case of C. Salvius Gratus, the cognomen Gratus was equally used by citizens, freedmen and slaves: Roffia (supra n. 83) 123.

[153] G. Lehrer-Jacobson, "Greek Names on Prismatic Jugs," *JGS* 34 (1992) 35–43; Trowbridge (supra n. 3) 120–28 provides a list of Greek and Latin names and letter combinations found on glass vessels but it is obviously outdated by the numerous finds that have come to light since the publication of her study in 1930; some of these are mentioned in *EAA*, Supplement 1970, s.v. *vitrarius* (M.C. Calvi).

[154] L. Taborelli, "Contenitori di vetro con bollo: Un caso esemplare della loro problematica," *Rivista archeologica dell'antica provincia e diocesi di Como* 177 (1995) 71–87; Taborelli, "Riflessioni sul caso di un bollo vitreo con *tria nomina* forse ridotta a sigla," in *Athenaeum Studi di Letteratura e Storia dell'Antichità* (Università di Pavia) 86.1 (1998) 287–89, pls. I, II. On names of glassblowers indicating freedmen: supra p. 457.

[155] E.g. *Paulinos Antiocheus* (nominative, in Greek, "Paulinos of Antiocheia"): Barag (supra n. 103) 109–11, figs. 1–3; and "*Tiberinou Chio[u]*" (genitive, in Greek, "of Tiberinos of Chio[s]"), from Tharros, Sardinia: G. Pesce, in *StSard* 14/15 (1955/57) 356 and fig. 104 (interpreted as "*chio[n]* (wine measure) of Tiberinos"). On the problem of interpreting toponymics: Stern 1995, 72.

[156] Sternini 1993 (supra n. 146) 85–88, Group II (with lit.). See also A. Frova, "Vetri romani con marchi," *JGS* 13 (1971) 36–44; J. Price, "Roman Unguent Bottles from Rio Tinto (Huelva) in Spain," *JGS* 19 (1977) 30–39; L. Taborelli, "Vasi di vetro con bollo monetale," *Opus Rivista Internazionale per la Storia Economica e Sociale dell' Antichità* 1.2 (1982) 315–40; Taborelli, "Nuovi esemplari di bolli già noti su contenitori vitrei dell' area centro-italica," *Picus* 3 (1983) 23–69; Taborelli, "A proposito della genesi del bollo sui contenitori vitrei," *Athenaeum* 63 (1985) 198–217; Sternini et al. 1997 (supra n. 146) 77–90.

[157] H. Büsing, "Der Münzabdruck im Boden einer Glasflasche von Ficarolo (I)," *AntW* 22 (1991) 21.

[158] Sternini 1993 (supra n. 146) 91.

[159] L. Taborelli, "Sulle *ampulle vitreae*. Spunte per l'approfondimento della loro problematica nell'ottica del rapporto tra contenitore e contenuto," *ArchCl* 44 (1992) 309–28, fig. 1.

[160] Morel (supra n. 38) 258–61; L.A. Scatozza Höricht, *I vetri romani di Ercolano* (Rome 1986) 22 gives the overall percentages of glass and thin-walled pottery in the site museum at Herculaneum as 260 glass vessels (71.04%) and 106 thin-walled pottery (28.96%). At Cosa, thin-walled pottery went out of use in the Claudian-Neronian period (41–68): M.T. Marabini Moevs, *Roman Thin Walled Pottery from Cosa (1948–1954)* (*MAAR* 32, Rome 1973) 45.

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commercial contacts ranging from north Italy to Gaul, Asia Minor, and Syro-Palestine. Significantly, this commerce was geared more toward trade in single objects and small quantities or series than large-scale bulk imports.[161] This is also borne out by the glass vessels recovered from shipwrecks (see below).

Beginning in the early second century, vessels for sale tend to come from fewer sources and from a more restricted area than previously. An evaluation of the glass excavated at Colchester concludes that by the early second century, the city "would have been supplied with glass produced by local centres, by centres further afield in the province (i.e., Britain), and almost certainly by imports from the Rhineland, Belgium and northern France."[162] Increased regional production destined for regional markets appears to have been typical for many trade goods.[163]

Whereas the influx of technology and industry led to economic growth in Gaul and the northwest provinces of the empire, Italy at the end of the second century began to experience a depopulation and an economic crisis that affected all areas of life in the peninsula. In the archaeological record of north Italy the crisis is tangible even earlier, beginning in the second half of the second century.[164] Problems for the glass industry may have begun earlier still. The decrease of vessel glass postdating the first century is now becoming increasingly obvious. Areas that were at the forefront of luxury production for conspicuous consumption in the mid-first century (see figs. 11, 12), producing not only for local markets but also for export, appear to have dropped out of business toward the end of the century. A rough count of the glasses in museums in northeast Italy (Veneto) suggests that luxury tablewares were not readily available in the second century. Glass usage was dominated by plain but good quality glass plates, storage bottles, simple household unguentaria, and glass cinerary urns, most of which were probably produced regionally. Finds from controlled excavations in northwest Italy suggest that in the third century relatively simple glass vessels were indicators of wealth.[165] The designation of Milan as one of the capitals of the empire (end of third century) signaled the beginning of economic revival in north Italy. Costly engraved glass tablewares, occasionally decorated with unprotected gold foil on the exterior, are imports from the Rhineland (Cologne) and from Rome.[166] There is no evidence for the production of luxury glass in north Italy in the fourth century. Glass cups, beakers, and bottles produced in the region (at Aquileia?) were available for domestic use.

In general, the manufacture and the sale of locally-made household wares were probably not widely separated. In Italy the production of fine glass tableware peaked in the first century, a period when artifacts were "commonly produced within the household or in small workshops appended to stores, where independent craftsmen sold their finished products on a local scale."[167] There is archaeological evidence for a glassblower/retailer from the Byzantine period (see below).

When the glassblower doubled as a shopkeeper, this involved a whole new set of opportunities for different types of cooperative agreements and hiring practises. Cash flow would have been a never-ending problem for those manufacturers who were also shopkeepers. In second-century Jewish circles, where Rabbi Akiba's saying, "The shopkeeper extends credit," was held in honor,[168] buying on credit, whether wholesale or at the retail level, appears to have been the rule. The owner of a commercial

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[161] Morel (supra n. 38) 250–51.

[162] Cool and Price 227.

[163] Panella (supra n. 74) 431–37; one may also compare the glass finds from the villa at Settefinestre: G. DeTommaso, "Vetro," in *Settefinestre: una villa schiavistica nell'Etruria romana* 2: *La villa e i suoi reperti* (Modena 1985) 173–211.

[164] L. Brecciaroli Taborelli, "Il vasellame da mensa in età tardoantica," *Archeologia in Piemonte* 2: *L'età romana* (Torino 1998) 271–89. On the crisis in Italy, its effects and its probable causes: Panella (supra n. 74). See also Panella, "Merci e scambi nel Mediterraneo tardoantico," *Storia di Roma* 3.II (Torino 1993) 613–97.

[165] Brecciaroli Taborelli (supra n. 164) 273–75; *Vetro e vetri* (supra n. 11) 77–128. Compare the glass excavated in cemeteries at Asti, Alessandria, Susa, Brescia, and Voghenza. Glass in north Italian museums: Calvi (supra n. 11); G.L. Ravagnan, *Vetri antichi del Museo Vetrario di Murano* (Corpus delle collezioni archeologici del vetro nel Veneto [CCAVV] 1, Murano 1994); S. Bonomi, *Vetri antichi del Museo Archeologico Nazionale di Adria* (CCAVV 2, Murano 1996); A. Larese and E. Zerbinati, *Vetri antichi di raccolte concordiesi e polesane* (CCAVV 4, Murano 1998); G. Zampieri, *Vetri antichi del Museo Civico Archeologico di Padova* (CCAVV 3, Murano 1998). A similar decline, beginning slightly later, has been noted in the Ticino area: Maccabruni (supra n. 145); S. Biaggio Simona, *I vetri romani provenienti dalle terre dell'attuale Cantone Ticino* (Locarno 1991) 27–29; *HelvArch* 22 (1991) 78–143.

[166] F. Paolucci, *I vetri incisi dall'Italia settentrionale e dalla Rezia nel periodo medio e tardo imperiale* (Firenze 1997) 196–97; Brecciaroli Taborelli (supra n. 164) 275–77. On local production for regional use: M. Buora, "Una produzione artigianale di un vetraio a Sevegliano (agro di Aquileia, Italia settentrionale) nel IV sec. d.C.," *JGS* 39 (1997) 23–31.

[167] Aubert (supra n. 84) 201.

[168] Mishna Aboth 3:16, cited after Goitein 151 and 438, n. 8.

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flower garden at Pompei, however, greeted everyone who crossed the threshold into his house with the words CRAS CREDO "I will give credit tomorrow" inlaid in the mosaic doormat at the entrance.[169]

Some glassblowers may have diversified their stock and sold products made by colleagues/partners (glassblowers and other artisans). Similarly, pharmacies and drugstores sold glass vessels that they filled with herbs and scents. Many fragments of small glass unguentaria and a few almost complete bottles were excavated in a commercial flower garden at Pompei.[170] Epigraphical evidence indicates that in Pompei glassworking and the sale of frankincense were concentrated in the same part of the city: *regio clivi vitrari sive vici turari* "the quarter of the glassworkers also known as the quarter of the frankincense dealers."[171]

Imported glassware appears to have been sold in combination with imported pottery. A mid-first-century store at Colchester stocked a selection of glass vessels in addition to Samian ware and various other types of fine pottery and clay lamps. The glass vessels had been stacked on shelves above the pottery. When fire destroyed the store (ca. 50–55) much of the glass melted and dripped down on the pottery. Nevertheless, several glass vessel shapes have been identified: shallow sagged bowls, plates, natural bluish-green ribbed bowls and the more luxurious monochrome blue and polychrome mosaic ribbed bowls. Blown vessels included small cylindrical cups of the type known as Hofheim cup (see fig. 14), a yellow skyphos, and a cylindrical bottle.[172]

An even more mixed assortment of pottery, glass, and lamps made up a merchant's stock at Cosa, destroyed in 40–45 when one of the walls of the forum-basilica collapsed: Arretine pottery, amphorae, lamps, thin-walled tablewares, coarse pottery, and 76 glass vessels. The glass included mold-formed, ribbed, mold-blown, and free-blown vessels, including an amazing variety of fine tablewares. The preliminary publication documents at least 31 different vessel shapes, which means that most shapes for sale were available in very small quantities.[173]

At the time of its destruction in 79, a shop near the forum of Herculaneum held a contingent of glass vessels packed in straw and other materials and divided into separate packages according to vessel shape. The glass vessels included:[174] 10 monochrome shallow ribbed bowls (Erc. 2a), two small bowls with tubular rims and base-rings (Isings Form 44a, Erc. 8), six large bowls (Isings 44b, Erc. 8), another large bowl (Isings 42, Erc. 9), four undecorated ladles and four with spiral thread (Erc. 17), one tall, straight-walled mold-blown beaker (Isings 31, Erc. 19), two indented beakers (Isings 32, Erc. 21), three cylindrical beakers (Isings 30, Erc. 23); one square bottle marked P. GESSI AMPLIATI (Erc. 25), one cylindrical bottle (Isings 51b, Erc. 25), one bulbous jug with upturned spout (Erc. 29), one mold-blown cup shaped like the head of a black (Erc. 33), two aryballoi with dolphin handles (Erc. 40), one small spherical bottle (Erc. 41), one small spherical bottle (Erc. 46), two tubular unguentaria (one Erc. 47a, the other Erc. 47d), three piriform unguentaria (Erc. 49), one carinated bottle (Erc. 50), perhaps one urn with M-shaped handles (Erc. 57), and one lid (for an urn) (Erc. 59). Apparently, the glass tablewares were sold in sets, like metal and pottery.

The buying of glassware in sets is also documented by the presence of sets in houses in Herculaneum as well as in first-century tombs throughout the Roman empire. Glass sets were found in tombs at Vervoz, Belgium (dated 60–75), at Saintes, southwest France (40–60), in Dalmatia (first century), and at Vize, Eastern Thrace (mid-first century, possibly before 44).[175]

Literary evidence attests the use of glass sets in Egypt. In a letter ascribed to the early second century a certain Claudius Terentianus lists among the

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[169] W.F. Jashemski, "The Garden of Hercules at Pompeii (II.viii.6): The Discovery of a Commercial Flower Garden," *AJA* 83 (1979) 403–11, esp. 410.

[170] Jashemski (supra n. 169) 407.

[171] *ILS* 1224b, quoted by Isings 5, with n. 3. On connections between medicinal preparations and glass containers: L. Taborelli, "I contenitori per medicamenti nelle prescrizioni di Scribonio Largo e la diffusione del vetro soffiato," *Latomus* 55 (1996) 148–56.

[172] H.E.M. Cool, "The Boudiccan Uprising and the Glass Vessels from Colchester," *Expedition* 38.2 (1996) 52–62, esp. 57–58 and fig. 9.

[173] F. Grose, "Roman Glass of the First Century AD. A Dated Deposit of Glassware from Cosa, Italy," *AnnAIHV* 6, 1973 (Liège 1974) 31–52.

[174] On the shop on the Decumanus Maximus: de Franciscis (supra n. 151); Scatozza Höricht (supra n. 11). The following compilation is made from Scatozza Höricht (supra n. 162); the numbers preceded by "Erc." refer to her forms.

[175] M.-C. Gueury and M. Vanderhoeven, "La tombe gallo-romaine de Vervoz aux Musées Royaux d'Art et d'Histoire," *BMusBrux* 60 (1989) 107–24; H. Chew, "La tombe gallo-romaine de Saintes. Nouvel examen du matériel," *Antiquités Nationales* 20 (1988) 35–61; M.R. DeMaine, "The Northern Necropolis at Emona: Banquet burials with ladles," *AnnAIHV* 11, 1988 (Amsterdam 1990) 129–44; A.M. Mansel, "Les fouilles de Thrace," *Belleten* 4 (1940) 115–39, esp. 133 with figs. 47–49.

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objects he is sending from Alexandria to Karanis:[176] *et accipias caveam gallinaria(m) in qua ha[bes] sunthe[seis] vitriae et phialas quinarias p[ar u]nu<m> et calices paria sex.* . . . "Receive also a chicken coop, in which you have sets of glassware, two bowls (lit. "one pair") of quinarius size, a dozen goblets (lit. "six pairs"). . . ." A second-century papyrus from Oxyrhynchus indicates that glass was bought even in half-sets: "Account of articles at order of Eugenetor in a double sack: (. . . .) 2 *procheiria* (handboxes) containing 3 *hemisyntheseis* (half-sets) of glass, 4 . . . *poteria* (drinking cups) and 1 . . ., 4 *batellai* (plates), 2 *skoutlia* (bowls), 1 *oxybaphon* (saucer)."[177] In fourth-century Karanis, excavated sets of glass were almost entirely composed of dishes, bowls, jars, flasks, and jugs. Well-to-do residents stored glass tablewares together with red-polished pottery dishes in baskets and boxes, and in pithoi that either stood on the floor or were sunk into it.[178] A late fourth-century shop at Corinth stocked glass and pottery vessels of the same shape,[179] suggesting the shopkeeper had ordered them specially to sell sets in different materials.

In the row of Byzantine shops abutting the Synagogue at Sardis, two adjoining double-story shops, probably Jewish owned or managed, contained large amounts of broken glass vessels and window panes dated to the fifth–sixth centuries. There is evidence for a dye shop on the lower floor.[180] The reports do not specify whether the glass fragments were from new or from used vessels. If the fragments were not from broken glass assembled for recycling, their large number suggests they might represent one or more deposits destined for wholesale (to local shops? for regional export?). Apparently, the two shops were located not far from the manufacturing facilities.[181] The glass vessels from shop E12 included "globular vessels, bottles, numerous glass lamps, goblets, concave vessel bases, and 350 window panes." A "closet" in the stairway was filled with fragments of glassware. Shop E13 yielded a total of about 4000 glass fragments: 90% vessels, 10% window panes. The vessels included "two lamps, over 350 goblets, a salver, base-rings, a cup or bowl, cylindrical bottles, many conical necked bottles (tapering both up and down), one bottle with a funnel neck" and glass rods.[182]

A Byzantine glass shop (sixth–seventh century) was recently excavated in the center of Bet She'an, near the bazaar.[183] It consisted of two connecting rooms and a courtyard. From the description it appears that this shop was run by the glassblower. The wall of one of the two rooms showed traces of shelves for storing glass vessels, but most of the glass objects appear to have been found in the other room that opened eastward onto the street and also contained the furnace—a setup that suggests the furnace (and the glassblower) benefited from the draft entering through the door.[184] The front room was divided into two workspaces, where "numerous glass vessels—many of them intact—found along the walls and in several concentrations, had been stored on shelves, racks of shelves or in baskets." The shapes were common utilitarian shapes for daily use: two types of lamps for use in a polycandelon, goblets, spherical or piriform bottles, small jugs with large loop handles, bowls, and window panes (round and rectangular).

Long-Distance Trade within the Roman Empire

Most long-distance trade in glass took place within the borders of the Roman empire. Archaeological evidence suggests this trade was concerned primarily with raw glass and fine tableware, though not exclusively, as can be seen by the occasional recovery of prismatic bottles from shipwrecks.[185] Glass was preferably shipped by sea since it was much more economical to transport goods over water than over land. The PE provides evidence for the cost of transport. A cart load of 1200 pounds (388 kg) cost 20 denarii per mile; a donkey load, probably of 200 pounds (65 kg), cost 4 denarii per mile (PE 17.3–5 combined with PE 14.8–11). Based on these prices, DeLaine has calculated the following average costs of transport: 0.52 KM per ton per Roman mile for ox-carts, 0.12 KM per ton per Roman mile upstream, 0.059 KM per ton per Roman mile downstream, and 0.012 KM per ton per Roman mile by sea.[186] With a specific gravity of ca. 2.60, ancient

[176] H.C. Youtie and J.G. Winter, *Papyri and Ostraca from Karanis* (Michigan Papyri 8, 2nd ser., Ann Arbor 1951) no. 468, lines 15–18.

[177] *P Oxy.* vol. 4, no. 741.

[178] D.B. Harden, *Roman Glass from Karanis* (Ann Arbor 1936) 34–38.

[179] C.K. Williams and O.H. Zervos, "Corinth, 1982: East of the Theater," *Hesperia* 52 (1983) 24–25, pl. 10: 64, 65.

[180] J.S. Crawford, *The Byzantine Shops at Sardis* (*SardisMon* 9, Cambridge 1990) 78–86; von Saldern (supra n. 9). The dye shop mentioned by Crawford p. 79.

[181] Von Saldern (supra n. 9) 95.

[182] Crawford (supra n. 180) 78–79.

[183] Gorin-Rosen 1998 (supra n. 9) 27–29.

[184] The primitive furnaces in Egypt and Afghanistan were also oriented in such a way as to benefit from the draft: Reut (supra n. 40), Henein (supra n. 40).

[185] Parker (supra n. 149) 197, no. 464, sunk ca. 200 near Grado carrying, inter alia, square bottles marked by C. Salvius Gratus; see also supra ns. 33 and 83.

[186] DeLaine 210–11.

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soda-lime-silica glass weighed ca. 2,600 kg per cubic meter.[187] Weight would have been a primary concern in deciding which type of transport to choose for shipping raw glass if a choice was available. With shipments of vessel glass, volume and the fragility of the merchandise would have made transportation by boat attractive.

In addition to their own cargo, most shippers also carried merchants with their wares, charging them passage money and for freight. The distinction between shipowner (*navicularius/naukleros*), captain (*magister/kubernetes* or *pronaukleros*), and merchant (*mercator, negotiator/emporos, pragmateutes*) or his agent (*pistikos*) was fluid: one man might fill all these roles at once.[188]

Guilds, religious communities, and resident fellow countrymen, organized in *stationes*, assisted members travelling abroad. Shipping companies from all over the Mediterranean had offices in Ostia; logotypes announcing their names and specialties can still be seen in the mosaics of the Piazzale delle Corporazioni. Many eastern Mediterranean cities were represented in the Roman forum; the Tyrians and Beirutians had offices in Pozzuoli. Whereas Syrians played an important role in the early Roman empire, Jews became increasingly visible in the fourth century.[189] The active role played by eastern Mediterranean merchants in the long distance sea trade may to some extent account for similarities between glass shapes made in the eastern and western part of the Roman empire.

Although findspots indicate extensive trade in pottery tableware, lamps, and glass, these commodities were never a major item of cargo on shipwrecks discovered in the Mediterranean.[190] Nine wrecks of Roman ships carrying glass vessels in their cargo have been identified: of these five date from the first century,[191] three from the second and third centuries,[192] and two are of uncertain date.[193] All of these ships sank in the western Mediterranean. The dates are consistent with an overall pattern of sea trade indicating that it was most intense in the late Republican and early Roman Imperial periods.

Most ships did not carry large amounts of vessel glass (on raw glass see below), nor was glass the sole or main cargo. The trade in glass vessels was probably handled by general merchants who took on individual consignments of glass.[194] It is sometimes difficult to distinguish a merchant's goods[195] from his personal property,[196] since in most cases the quantity of glass they carried is small and varied. Thus, the status of the few and varied glass vessels excavated at Port Vendres and Mellieha Bay[197] is not clear. A basket filled with nine glass unguentaria, some still holding the remains of a cosmetic, may be evidence for an individual consignment on board a ship that sank in the harbor at Fos-sur-Mer in the mid-second century.[198]

Individual consignments were probably common also in overland trade. At Kempten (southern Germany) a small concentration of ca. 12 square glass jugs among 89,565 kg of Rheinzabern Samian pottery, ironwork, and bronze suggests a wholesale rather

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[187] I thank Fred E. Schaefer, Toledo, for this calculation, which is based on the fact that ancient glass was denser (contained proportionately less silica) than modern soda-lime-silica glass which has a specific gravity of 2.50. For comparison, the specific gravity of quartz (rock crystal) is 2.65, marble 2.72, and oakwood 0.75.

[188] J. Rougé, *Recherches sur l'organisation du commerce maritime en Méditerranée sous l'empire romain* (Paris 1966) 214–94; A.H.M. Jones, *The Later Roman Empire 284–602* (Oxford 1964, repr. 1973) 866–71.

[189] Rougé (supra n. 188) 302–19. On trade with Britain: J. du Plat Taylor and H. Cleere eds., *Roman shipping and trade: Britain and the Rhine provinces* (Council for British Archaeology Research Report 24, 1978).

[190] Parker (supra n. 149) 16–17.

[191] Parker (supra n. 149) no. 283 (Cavallo A); no. 584 (Lavezzi A); no. 875 (Port Vendres B; more on the glass in A.J. Parker and J. Price, "Spanish Exports of the Claudian Period: The Significance of the Port Vendres II Wreck Reconsidered," *IJNA* 10.3 [1981] 221–28, esp. 224–27); no. 1174 (La Tradeliere; on the glass from this wreck, see also M. Feugère and F. Leyge, "La cargaison de verrerie augustéenne de l'épave de la Tradelière [Iles de Lérins]," in M. Feugère ed., *Le verre préromain en Europe occidentale* [Montagnac 1989] 169–76). Narbonne: M. Feugère, "Un lot de verres du 1er siècle provenant du port de Narbonne (Aude)," *RANarb* 25 (1992) 177–206.

[192] Parker (supra n. 149) no. 464 (Grado); no. 691 (Mellieha); and no. 906 (Procchio).

[193] Parker (supra n. 149) no. 530 (La Jaumegarde A) and no. 614 (Maddalena).

[194] On mixed cargoes and numbers of merchants sailing on Roman ships: G.W. Houston, "Ports in Perspective: Some Comparative Materials on Roman Merchant Ships and Ports," *AJA* 92 (1988) 553–64, esp. 558.

[195] Ship wrecks containing glass vessels thought to be commercial consignments rather than personal properties of travellers were found, inter alia, at Antikythera (late Hellenistic): G.D. Weinberg, *Glass Vessels in Ancient Greece* (Athens 1992) 28–33; la Tradelière, Narbonne, and Cavallo I (ca. 50–60): supra n. 191; Serçe Limani (11th c.): G.F. Bass, "The Nature of the Serçe Limani Glass," *JGS* 26 (1984) 64–69.

[196] Parker (supra n. 149) lists 21 wrecks of the Roman and early Byzantine periods containing glass thought to have been used on board.

[197] Supra ns. 191, 192.

[198] Parker (supra n. 149) 373–74, no. 1002 (Saint Gervais C).

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than a retail depot.[199] The remains of what appears to have been a wholesale contingent of glass have been excavated at Augsburg. Dated to the Flavian period, the finds include over 600 individual glass vessels representing some 40 shapes and subtypes. The vessels are thought to come from one large shipment of glass from north Italy (perhaps Aquileia) that was damaged before it could enter the retail circuit.[200]

The practice of taking on individual consignments is similar to business practices in medieval Mediterranean trade and commerce. Numerous Geniza documents and business letters record the workings of a trade based on individual consignments. Timing was of the utmost importance. Business letters often ended with lists of that day's prices for a wide range of goods. Vendors aimed to be first on the market. Countless letters advise the addressee to send a commodity "with the very first ship sailing" or to sell immediately upon arrival. Business relationships included "friendship" and other forms of informal cooperation that might last for a lifetime, partnerships and commenda (in principle for short term duration and limited to specific undertakings), family partnerships, commissions and agencies.[201]

Adequate packing was important for glass vessels. Egyptian papyri from the Roman period mention glass vessels packed in a *cavea gallinaria* "chicken coop," a *procheirion* "handbox," and a *panarion* "bread basket."[202] Archaeological evidence confirms the practice. The nine glass unguentaria from Fos-sur-Mer were transported in a basket; the second-to-third century glass vessels from the wreck in Mellieha Bay were packed in a hardwood box.[203] Basketry and papyrus were the preferred packaging materials in Egypt, while straw was more common in the West.[204] In some cases, the glass vessels themselves contained the merchandise, for example, the unguentaria from For-sur-Mer and perhaps some prismatic bottles. It has been suggested that some large late Roman and early Byzantine glass containers served to transport wine and fish sauce.[205]

The direction of the trade in Roman glass vessels is an intriguing question. While it is generally assumed that most trade in the first century went from the Syro-Palestinian coast to the North Pontic cities and Italy, the possibility of trade in the opposite direction, from Italy to the Syro-Palestinian coast, is also very likely. The dominance of Italy and the West in early glassblowing suggests glasses made in the West were exported to the East,[206] not only to the coasts of the Black Sea where the Romans had a foothold[207] but even to Syria and Palestine. Anomalous finds such as several modioli and a large, one-handled squat cylindrical bottle[208] were probably personal belongings that do not represent regular trade. For other shapes the question can only be addressed when more data is available and reliable distribution maps have been made. Western-made glass vessels have come to light in the East in surprising numbers, such as the many Hofheim cups (see fig. 14).[209]

In many cities, the presence of a high quality local glassblowing industry appears to have created demand for *imported* fine wares. Excavations at sites known to have had a thriving glass industry frequently

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[199] M. Rhodes, "Roman Pottery Lost *en route* from the Kiln Site to the User," *Journal of Pottery Studies* 2 (1989) 44–58, esp. 45, 53, 54; on the bottles and other glass finds from Kempten: P. Fasold, "Die früh- und mittelrömischen Gläser von Kempten-Cambodunum," in *Forschungen zur provinzialrömischen Archäologie in Bayerisch Schwaben* (Schwäbische Geschichtsquellen und Forschungen 14, Augsburg 1985) 197–230, square bottles, pp. 200, 206–208, 218–22, no. 43, figs. 14, 15.

[200] For a preliminary discussion of the finds: Rottloff (supra n. 33) 166–70.

[201] Goitein 164–86.

[202] Youtie and Winter (supra n. 176) no. 468, lines 15–18; *P Oxy.*, vol. 4, no. 741, lines 14–15, and *P Oxy.*, vol. 10, no. 1294, line 6 respectively.

[203] Parker (supra n. 149) nos. 1002 and 691 respectively.

[204] E.g.: C.C. Edgar, *Greco-Egyptian Glass, Catalogue général des antiquités Egyptiennes du Musée du Caire* (1905, repr. Osnabrück 1974) nos. 32.655; 32.656; 32.661; F.J. Hassel, "Glasamphore im Deckelkorb," *JRGZM* 33 (1986) 908–909, fig. 94; de Franciscis (supra n. 151).

[205] L. Taborelli, "Indagine preliminare sui contenitori in vetro per trasporto e la conservazione del vino e del *garum*," *Opus* 12–13 (1993–1994) 1–23.

[206] J. Price, "Glass Tablewares in Use in Mytilene (Lesbos) in the 1st c. A.D.," *AnnAIHV* 14, 1998 (forthcoming) notes that many groups are similar to the glass excavated at Fréjus.

[207] N. Sorokina, "Das antike Glas der Nordschwarzmeerküste," *AnnAIHV* 4 (Liège 1967) 67–79, esp. 77; Sorokina, "Facettenschliffgläser des 2. und 3. Jhts. u. Z. aus dem Schwarzmeergebiet," *AnnAIHV* 7, 1977 (1978) 111–22, esp. 122; Sorokina, "Glass Aryballoi (First–third Centuries A.D.) from the Northern Black Sea Region," *JGS* 29 (1987) 40–46, esp. 43.

[208] Modioli and squat cylindrical bottle from Syro-Palestinian findspots: Stern (in prep.). Five small square bottles and two small cylindrical bottles from tombs at Castra look very similar to those made in the West: Y. Gorin-Rosen, *Ancient Glass from the Holy Land*, exhibition catalogue, Fine Arts Museum of San Francisco/Israel Antiquities Authority (1998) 20; Y. Gorin-Rosen, presentation at 14th congress of the Association Internationale pour l'Histoire du Verre, Venice/Milan 1998.

[209] Isings Form 12. On Hofheim cups in general: Cool and Price 64–68; on eastern Mediterranean finds: Stern (in prep.).

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yield more imported glass vessels than sites where no glass was blown. Pompei and Aquileia are good examples of cities in Italy where local glassworking and imported glass vessels are attested in quantity.

Unlike the finished glass object whose potential buyers were numerous and located throughout the empire and beyond, raw glass was destined for a small, select number of clients whose workshops specialized in the production of luxury or utilitarian wares. It has recently been suggested that the merchants who provisioned the workshops with raw glass might have done so in return for a specified part of the production as was to become customary much later in medieval France.[210] In a situation described in the Babylonian Talmud (third century), Rabbi Huna explains the different Sabbath rules for when a merchant needs to unload finished vessels and chunks of raw glass from his donkey's pack.[211] The Talmud citation shows that one merchant might bring raw glass and/or cullet to the glassblower and leave with finished vessels. There is, however, no evidence of a formal business arrangement for this type of transaction either in the Roman period or in the Geniza documents.

Archaeological evidence for long distance sea trade in raw glass reflects the important changes that took place in glassmaking and glassworking at different periods in history. Up to the late Hellenistic period, almost all glass objects were made of intentionally colored or decolorized glass. Expensive and produced in small quantities, colored glass was sold in the form of preformed ingots. Long distance trade in ingots is illustrated by the carefully packed cakes of colored glass excavated in a Bronze Age ship that sank off the southwest coast of Turkey, at Ulu Burun.[212] Glass finds from later shipwrecks are evidence that preformed ingots remained the norm for trade in colored glass during the Roman empire.[213]

Natural bluish-green glass became common in the late Hellenistic period, although it was a trade good as early as the third century B.C.[214] The bulk density of glass is higher than that of sand or clay, which was commonly used as ballast. Sold in the form of amorphous chunks, the raw glass could be transported by sea at almost no cost because it doubled as ballast. A first-century shipwreck excavated off the Croatian coast at Mljet yielded more than 100 kg of natural bluish-green raw glass, dispersed throughout the area of the wreck.[215] Chunks of transparent blue-green glass were discovered off the Israeli coast at Apollonia/Arsuf and Carmel Beach. Whereas the glass off Carmel Beach is thought to be from a third-century merchant ship "sailing between the shores of Lebanon and Alexandria," glass was also made locally at Apollonia/Arsuf.[216]

Once recycling became common, cullet could become part of the ballast, preferably mixed with raw glass because cullet has a lower bulk density than raw glass. An Islamic ship that sank at Serçe Limani carried 3 metric tons (3,000 kg) of glass "both in the form of chunks of raw glass and broken vessels" (cullet) as ballast in its hold.[217] For comparison, a Geniza document dated 1011 mentions 37 bales of glass (at about 227 kg each) sent by three Jewish firms from Tyre, that is, a total of more than eight metric tons, (8,399 kg, to be precise).[218]

It is not clear how the transportation of this much glass as a ship's ballast was organized, and whether the initiative was with the glassmaker, the buyer, or the merchant/ship's owner. Perhaps the latter sold

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[210] Nenna et al. (supra n. 8) 86.

[211] Weinberg 25, n. 2.

[212] G.F. Bass, "A Bronze Age Shipwreck at Ulu Burun (Kas): 1984 Campaign," *AJA* 90 (1986) 269–96; Bass, "Splendors of the Bronze Age," *National Geographic* 172 (1987) 693–733; Parker (supra n. 149) 439–40, no. 1193. See also R.J. Charleston, "Glass 'Cakes' as Raw Material and Articles of Commerce," *JGS* 5 (1963) 54–68; D. Barag, *Catalogue of Western Asiatic Glass in the British Museum* (London 1985) 107–110; Stern 1999 (supra n. 109).

[213] Ingots of raw glass: Parker (supra n. 149) 221, no. 530 (ca. 100–25 B.C., blue glass ingots) and 274, no. 691 (ca. 200–250, cakes of glass, blue frit). See also D. Foy and M. Picon, "Lingots de verre en Méditerranée occidentale (3e siècle avant J.-C.–5e siècle après J.-C.)," *Ann-AIHV* 14, 1998 (forthcoming).

[214] M.-D. Nenna, "Les ateliers de verriers dans le monde grec aux époques classique et hellénistique," *Topoi* 8 (1998) 693–701, esp. 696: shipwrecks Sanguinaire A (near Ajaccio) and Lequin 2 (Ile de Porquerolles), both carrying chunks of glass and both dated third century B.C.

[215] I. Radic and M. Jurisic, "Das antike Schiffswrack von Mljet, Kroatien," *Germania* 71 (1993) 113–38, esp. 122–23. On ingots and chunks of raw glass from land and underwater excavations in the western Mediterranean, see also Picon (supra n. 49) and D. Foy, "Archéologie: Une épave chargée de lingots et de vaisselle de verre," *Verre* 3.3 (1997) 65–70.

[216] E. Galili et al., "Underwater Surveys and Rescue Excavations along the Israeli coast," *IJNA* 22.1 (Febr. 1993) 61–77, esp. 65 (Apollonia/Arsuf) and 70 (Carmel Beach, Haifa). Glassmaking at Apollonia Arsuf is mentioned by Gorin-Rosen (supra n. 208) 15. Two large chunks of blue-green glass from Apollonia/Arsuf, shown in the exhibition (supra n. 29), are labeled "second century BCE–first Century CE."

[217] Bass (supra n. 195) 64–69, esp. 64; Parker (supra n. 49) 398–99, no. 1070.

[218] Goitein 421, n. 65; on the weight of a bale, ibid. 335.

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the glass, upon arrival in port, to middlemen or representatives of workshops. Small amounts of specialized, colored raw glass could perhaps be ordered directly from a business partner near the factory and transported as one merchant's consignment.

Trade beyond the Frontiers

Before speaking about trade beyond the frontiers, it is useful to remember that "Roman glass" is a catchall term for glass made during the first through fourth centuries. It includes objects made within the borders of the Roman empire *and* beyond, for example, in Mesopotamia and the Hellenized cities of the north coast of the Black Sea. "Roman glass" has come to light in excavations far beyond the frontiers, in north, central, and southeast Europe and in Africa, India, and eastern Asia.

In western Europe, the Roman military played an important role in introducing glass and glassworking to the provinces. Roman legionaries, composed of ethnic groups from all corners of the empire, guarded the borders along the Rhine and Donau rivers. When legions were transferred they were usually accompanied by craftsmen and artisans, including glassworkers to produce windowglass (appreciated in a raw climate) and supply soldiers with tableware. As a result the expansion of the Roman empire in the first century saw important glass centers spring up in the new provinces northwest and northeast of Italy. Many soldiers came from the eastern Mediterranean, where glass was part of the *instrumentum domesticum.* Elegant glass services imported from Italy graced the officers' tables.[219] The civilian population increasingly demanded the accoutrements of Roman life. Glass tablewares became symbols of culture as well as realistic indicators of wealth and social diversity.[220]

Diplomatic and commercial contacts with peoples living beyond the borders in Germany, Scandinavia, and central Europe created further interest in Roman utilitarian and luxury products. In this cultural and economic exchange, glass drinking vessels played a significant role, as suggested by the large number of Roman glass cups and beakers excavated in settlements and graves in Scandinavia and north-central Europe.[221] It is not clear to what extent the glass vessels from Scandinavia, north-central Europe, and northern Britain are evidence of regular (barter?) trade patterns or individual gift exchanges.[222] The glass from Scandinavia and Germania *libera* consists almost exclusively of luxury drinking vessels. This fixation on one function appears consistent with a greater pattern of exchange that included a similarly specialized array of imported metal wares, the majority of which were large buckets and basins. The imports included very little pottery. The limited number of functions associated with the imports from the Roman empire suggests to me that these objects were indeed part of an organized trade pattern in which a specific demand determined a specific supply. One is reminded of the seemingly exotic copper cauldrons stamped "made in Germany" that were offered for sale in markets throughout Greece in the 1960s. The demand for imported glass drinking vessels persisted after the demise of the Roman empire in the West. Excavations have yielded numerous fourth-to-sixth-century beakers of a high quality, colorless glass that was rare in the (former) Roman provinces of Europe. The shapes and decoration of these glasses became increasingly "unRoman." They may have been made in an as yet unidentified glass center outside the former Roman empire.[223]

One of the most surprising findspots of Roman glass is the Libyan desert (the Sahara). Italian excavations unearthed several deposits of glass in the area known as Fezzan.[224] Among the earliest glass were fragments of ribbed bowls and other vessels from a mausoleum at Germa (perhaps ancient Garama) that also yielded fine pottery dated to the late first century. Associated with the burial of a nonlocal person, these objects probably reached the site in the wake of an expedition to the Garamantes that took place in the Flavian period.[225] Most Roman

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[219] On the important role of the Roman army in introducing glass to western Europe: S.M.E. van Lith, "First-century Cantharoi with a Stemmed Foot: Their Distribution and Social Context," in *Two Centuries* 99–110; Stern 1995, 96.

[220] Van Lith and Randsborg 437–45.

[221] H.J. Egger, *Der römische Import im freien Germanien* (Atlas der Urgeschichte 1, Hamburg 1951); U. Lund Hansen, *Römischer Import im Norden. Warenaustausch zwischen dem Römischen Reich und dem freien Germanien* (Copenhague 1987). See also infra n. 223.

[222] On the difficulty of interpreting the evidence: Harris (supra n. 66) 15, 16.

[223] U. Näsman, *Glass and Trade in the Late Roman and Migration Periods. A Study on Glasses Found in Eketorp-II, Öland Sweden* (Uppsala 1984); E. Straume, *Gläser mit Facettenschliff aus skandinavischen Gräbern des 4. und 5. Jahrhunderts n. Chr.* (Oslo 1987).

[224] G. Caputo, "Scavi Sahariani: ricerche nell' Uadi el-Agial e nell' Oasi di Gat," *Mem. Accademia Nazionale dei Lincei* 41 (Rome 1951) 151 ff. (not available to me); *EAA* 6. 1014–15, s.v. Romana Arte (F. Coarelli).

[225] J. Desanges, *Recherches sur l'activité des Méditerranéens aux confins de l'Afrique* (Ecole Française de Rome 1978) 197–211 describes two Roman expeditions that passed through the area under the Flavians.

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glass from Fezzan was excavated in monumental tombs in the vicinity of the mausoleum. The glass vessels included a one-handled cylindrical bottle decorated with incised geometric designs, two conical beakers decorated with large dots (glass scholars call them blue 'blobs'), a shallow bowl with a wheel-cut inscription, and numerous engraved fragments, all of which date to the fourth century. The same date has been proposed for the glass excavated ca. 360 km farther southwest in the cemetery of Gat. The most spectacular find here was a painted beaker. These fourth-century finds may suggest (temporary?) trade.

Many sites in Sudan, south of Egypt, yielded luxury glass objects dating to the late Hellenistic and Roman Imperial periods.[226] Although some of the glass was probably local,[227] much was imported from or through Egypt along the Nile. When the Romans annexed Egypt the kingdom of Meroe remained independent, but relations between Egypt and its southern neighbors remained close until the second half of the fourth century.[228] Meroe was an important trading center through which many African luxury goods were channeled to the Mediterranean and beyond. Many fine glass vessels that found their way to Meroe may have played a role in this exchange.[229] A similar exchange took place with the ancient kingdom of Aksum through its port Adulis on the Red Sea.[230]

In East Africa and India, Roman glass was a regular trade good, both as finished objects and raw glass. An anonymous first-century manuscript written in Greek gives precise instructions on the commodities that could be sold and bought along two sea routes, one following the East coast of Africa as far south as Madagascar, the other using seasonal monsoon winds to cross the ocean to India. The manuscript, *Periplus Maris Erythraei* (hereafter *PME*), is a combined navigation guide and merchant's compendium. From this text we learn that several sorts of multicolored glass objects, thought to be mosaic glass inlays, were exported to the north coast of Somali, glass vessels to north India, and raw glass (*hyalos arge* "unworked glass") to south India. Excavations at various sites in these areas brought to light exactly the kinds of glass mentioned in the *PME*.[231] The trade routes mentioned in the *PME* began in Egypt, where some—but not all—of the glass exported to the East may have been produced. Several Red Sea ports took part in this trade; the most important were Berenike and Myos Hormos (recently identified as Quseir al-Qadim).[232]

Not all exotic findspots are necessarily evidence for regular trade in glass. The fragments of glass vessels excavated at Arikamedu, on the east coast of south India, are thought to represent personal possessions rather than items of trade.[233] Some of the most intriguing findspots in this connection are the island of Bahrain[234] and ed-Dur (Umm Al-Qaiwain, United

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[226] D. Dunham, *Royal Cemeteries of Kush* 4: *Royal Tombs at Meroë and Barkal* (Boston 1957) and 5: *The West and South Cemeteries at Meroë* (Boston 1963); J. Leclant, "Glass from the Meroitic Necropolis at Sedeinga," *JGS* 15 (1973) 52–68; R. Brill, "Scientific Investigations of Some Glasses from Sedeinga," *JGS* 33 (1991) 11–28.

[227] Stern 1979 (supra n. 14) 46, 47 (locally made inlays); H.E.M. Cool, "Sedeinga and the Glass Vessels of the Kingdom of Meroe," *AnnAIHV* 13, 1995 (Lochem 1996) 201–12 (vessels).

[228] Desanges (supra n. 225) 307–66.

[229] Cool (supra n. 227) 211.

[230] H. Morrison, "Glass and Trade of the Ancient Aksumite Kingdom," *AnnAIHV* 9, 1983 (Liège 1985) 113–126; Morrison, "The Glass," in S.C. Munro-Hay, *Excavations at Aksum* (London 1989) 188–209.

[231] On the glass mentioned in the *PME*: E.M. Stern, "Early Exports Beyond the Empire," in *Two Centuries* 141–54; Stern, "Early Roman Export Glass in India," in V. Begley and R.D. De Puma eds., *Rome and India: The Ancient Sea Trade* (Madison 1991) 113–24; C. Meyer, *Glass from Quseir al-Qadim and the Indian Ocean Trade* (Oriental Institute of the University of Chicago Studies in Ancient Oriental Civilization 53, Chicago 1992) 43–74; J. Desanges et al., *Sur les routes antiques de l'Azanie et de l'Inde* (Mémoires de l'Académie des Inscriptions et Belles-Lettres N.S. 13, Paris 1993). On the *PME*: L. Casson, *The Periplus Maris Erythraei. Text with Introduction, Translation and Commentary* (Princeton 1989). On the economics of the trade: S.E. Sidebotham, *Roman Economic Policy in the Erythra Thalassa 30 B.C.–A.D. 217* (Leiden 1986).

[232] S.E. Sidebotham and W.Z. Wendrich eds., *Berenike 1994. Preliminary Report of the 1994 Excavations at Berenike (Egyptian Red Sea Coast) and the Survey of the Eastern Desert* (CNWS, Leiden 1995); Sidebotham and Wendrich's 1996 Report includes a preliminary report on the glass finds by P.T. Nicholson, 279–88. On the Roman glass from Quseir: Meyer 1992 (supra n. 231). On the identification of Quseir al-Qadim as Myos Hormos: A. Bülow-Jacobsen et al., "The Identification of Myos Hormos. New Papyrological Evidence," *BIFAO* 94 (1994) 27–42; D.P.S. Peacock, "The Site of Myos Hormos: A View from Space," *JRA* 6 (1993) 226–32.

[233] Stern 1991 (supra n. 231); Stern, *BibO* 52 (1995) 833–40 (with lit.). In the medieval Indian trade, glass vessels feature primarily as household items, not as trade goods: S.D. Goitein, *Letters of Medieval Jewish Traders* (Princeton 1973) 185–92, letter 38, sent from Aden to India in 1139; the glass appears in Section D "household goods." On long distance trade in the early Middle Ages, see also Goitein and Meyer 1992 (supra n. 231) 98–103.

[234] E.C.L. During Caspers, *The Bahrain Tumuli An Illustrated Catalogue of Two Important Collections* (Uitgave van het Nederlands Historisch Instituut te Istanbul 47, Leiden 1980).

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Arab Emirates) on the Arabian Gulf. Both locations yielded first-century ribbed bowls and other fine glassware. The finds from the Belgian excavations at ed-Dur are of particular importance because they were recently unearthed during controlled excavations.[235] The catalogue of the glass vessels includes 122 objects ranging from 25 B.C. to A.D. 75. The manufacturing techniques include casting, mold-forming, free-blowing, and mold-blowing; decorative techniques include mosaic glass, tooled vessels, flecked wares, threaded, and wheel-cut vessels. The finds also include fine tableware (drinking vessels, jugs, a plate), luxury containers (a mold-blown pyxis, polychrome and mold-blown bottles) as well as utilitarian bottles and unguentaria. Most of these vessels were imported from the Roman empire, but some of the utilitarian bottles could have been made in Parthia.

Do these vessels represent items of regular trade or were they the personal belongings of Roman or Mediterranean traders who settled in the area? In view of the well documented glass trade with India, and the fact that smaller assemblages of Roman glass have come to light at other sites on the Arabian Gulf, it is tempting to interpret the glass from ed-Dur as trade goods. Three trade routes have been considered: 1) by sea from an Egyptian port like Quseir al-Qadim; 2) the overland route from Syria to the Euphrates, passing through Charax at the head of the Arabian Gulf; and 3) export from Egypt to India from where it was reexported to the Gulf.[236] The most compelling reason for suggesting the glass was exported first to India and then reexported from India to the Gulf: the *PME* scarcely mentions the Gulf, whereas Indian ships are known to have frequented the area. Similarities between the glass excavated at Quseir al-Qadim and the Arabian Gulf suggests much of the glass could have reached the Gulf through the Red Sea. However several observations suggest that at least some of the glass came overland: the presence of Parthian glass bottles, the presence of foreign coins minted at Charax, and the fact that "40% of the diagnostic pottery from ed-Dur was made in southern Iraq." Moreover, much of the glass from ed-Dur is similar to that found at Dura Europos.

Other important findspots of Roman glass in Asia include Taxila and Begram.[237] The glass finds from Begram are so diverse that individual groups of glasses have been assigned to periods 200–300 years apart, from the first to the third/fourth centuries. This is not the place to enter the controversy, however one unique group of Begram glasses, decorated with applied wavy coils for which no comparisons were known until recently, now has an exact parallel excavated in the vicinity of Padua in a tomb assigned to the late first century. If that date is correct, all the glass from Begram may well date from the first century.[238]

Roman and Sassanian glass travelled as far as China, Korea, and Japan. While some of the finds may have reached these areas by sea, through India and Sri Lanka, others may have travelled overland in a camel's load.[239]

GLASS IN A SOCIAL CONTEXT

Differences in quality, size, and workmanship are proof that Roman glass vessels, like textiles, ranged the entire spectrum from expensive luxury items to the simplest of utilitarian goods. The archaeological evidence is complemented by anecdotal literary sources. While some drinking cups were so inexpensive they could be bought "for a copper" (Strabo 16.2.25), two particular glass drinking cups of moderate size sold for 6000 sesterces in the time of Nero (Plin. *HN* 36.194).

A detailed analysis of individual topographical units at Augst showed that the quantity of glass finds alone cannot be used as a definitive criterion to determine social status. Large numbers of fine tablewares excavated in middle-class houses "contrasted sharply with the real rarity of finds in the luxurious residences of the upper class." This did not mean "that the socially well-off disdained the use of tableware glass";[240] the most expensive tablewares, made of mosaic glass and colorless vessels with wheel-cut decoration, were found predominantly in the better residential quarters. The highest concentration of

[235] D. Whitehouse, *Excavations at ed-Dur* 1: *The Glass Vessels* (Leuven 1998).

[236] The following discussion summarizes Whitehouse (supra n. 235) 65–67.

[237] J. Marshall, *Taxila* (Cambridge 1951) 683–90. P. Hamelin, "Verreries de Bégram," *CahByrsa* 2 (1952) 11–25; 3 (1953) 121–28; 4 (1954) 153–83.

[238] On the date of the glass from Begram most recently: M. Menninger, "Untersuchungen zu den Gläsern und Gipsabgüssen aus dem Fund von Begram (Afghanistan)," (Würzburg 1996), review by D. Whitehouse, *AJA* 102 (1998) 639–41. The glass beaker from Padua has not yet been published.

[239] E.J. Laing, "A report on Western Asian Glassware in the Far East," *Bulletin of the Asia Institute* 5 (1991) 109–20 provides a readily accessible survey of foreign glass vessels excavated in China, Korea, and Japan. See also: E.M. Stern 1995 (supra n. 233) 836 with n. 11; E.R. Knauer, *The Camel's Load in Life and Death* (Kilchberg 1998) 117–21.

[240] Rütti 342.

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windowglass was found in public buildings and the houses of the wealthy. Changes of usage over time were observed in individual houses and *insulae*.[241]

Most of the uses for blown glass known until the 19th century were explored during the first 100 years of commercial glassblowing, roughly coinciding with the first century A.D. Glass was often used in antiquity for purposes that, since the Middle Ages, have been commonly served by porcelain, a material unknown in the Roman empire.[242] Glass was nonporous, it did not contaminate the contents. Transparent glass even allowed inspection through the wall of a closed container. Although ancient literature contains many references to the functions of glass vessels, it is not always easy to assign a specific function to each individual type of vessel.[243]

To judge from excavated finds, glass vessels became widely accessible to all levels of society during Tiberius's reign (A.D. 14–37). The physician Scribonius Largo, active in the time of Claudius (41–54), mentioned glass containers for medicines as a matter of course.[244] Small bottles for scented oils, cosmetics, and medicines were among the earliest blown glass vessels. Tableware was a second area of early usage. Initially, blown-glass tableware served the same purpose as high quality Hellenistic glass tableware: drinking and serving. Very soon pouring became a major function. The great Roman tradition of glass jugs, flasks, and decanters began before the middle of the first century. Some of the earliest jugs were high quality mold-blown vessels made by Ennion.

In 70, Pliny (*HN* 36.199) noted that glass tableware had almost ousted silver and gold. The problem may have begun earlier, under Tiberius, who is said to have destroyed the workshop of a glassblower in order to avoid a devaluation of precious metals (*HN* 36.195). Glass continued to grace the tables of the wealthy into the fifth century because the material had the one great advantage that it did not affect the taste of wine, as metal does, an advantage which Nero's *arbiter elegantiae* Petronius (*Sat.* 50) aptly noted: "I prefer glass—that's got no taste at all. If only it didn't break I'd prefer it to gold."

The material's impermeability and cleanness were probably the reasons glass became the preferred material for large utilitarian containers. From the second half of the first century glass storage bottles began to compete with clay amphoras for storage and perhaps transport of liquids and solids.[245]

The last major contribution of glassblowing to society was the development of new vessels designed specifically for lighting purposes.[246] Unlike clay lamps, which were filled entirely with oil, glass lamps were filled with water upon which the oil and wick (steadied by a wick holder) floated. The choice of lamp depended on the type of light that was actually needed.[247]

Light emission studies show that glass lamps had the advantage of burning longer and almost twice as brightly as terracotta lamps. In terracotta lamps, the type of fuel made no difference. Filled with 50 ml of oil and a ½ cm-wide cotton twine wick, a terracotta lamp produced a steady candle power of 0.843 for 2 hours and 23 minutes. In glass lamps castor oil proved to be more satisfactory than olive oil. A glass lamp filled with 350 ml water and 100 ml castor oil burned with a smokeless flame for 2 hours and 45 minutes, needing only one adjustment of the wick. The output was a candle power of 1.36.[248] Pliny attests the use of castor oil in antiquity (*HN* 15.25–26) classifying it as an *oleum ficticium* "artificial oil." He described two different methods for extracting the oil from the *kiki* plant, which grew wild in Egypt. Writing long before the invention of glass lamps in which the oil floated on top of water, Pliny had no high opinion of castor oil. He called it disgusting for food and *lucernis exile* "of thin quality for burning in lamps."

The glass lamp appears to have been an eastern Mediterranean, perhaps Syro-Palestinian, innovation.[249] The earliest glass lamps were flat-bottomed hemispherical bowls with small loop handles that

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[241] Rütti 170–287.

[242] In 1134, a religious authority in Cairo was asked "whether translucent Chinese porcelain could be regarded as glass for ritual purposes" (Goitein 421, n. 67).

[243] On the functions of glass vessels mentioned in ancient literature: Trowbridge (supra n. 3) 150–93; W. Hilgers, *Lateinische Gefässnamen* (Dusseldorf 1969) passim.

[244] Taborelli (supra n. 171) 148–56.

[245] The contents of a square bottle from Pompei proved to be vegetable oil: Scatozza et al. (supra n. 145) 557–58. Cylindrical and prismatic bottles have recently been reviewed by Cool and Price 184–85. The earliest square bottles come from Cosa and the Port Vendres II wreck, both of which are firmly dated early to mid 40s. With a base width of ca. 4.5 cm, these bottles appear to have been relatively small.

[246] On glass lamps: G.M. Crowfoot and D.B. Harden, "Early Byzantine and Later Glass Lamps," *JEA* 17 (1931) 196–208; D.B. Harden, *Roman Glass from Karanis* (Ann Arbor 1936) 155–64; E.L. Higashi, *Conical Glass Vessels from Karanis* (Diss. Univ. of Michigan 1990); S. Hadad, "Glass Lamps from the Byzantine through Mamluk Periods at Bet Shean, Israel," *JGS* 40 (1998) 63–76.

[247] Higashi (supra n. 246) 378–79 notes that at Karanis, glass and clay lamps were often found in the same room of one house.

[248] Higashi (supra n. 246) 380–81.

[249] Stern (in prep.).

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Fig. 28. Conical lamp. H. 17.1 cm, wt. 317 g. Second half of fourth century. No pontil scar. Probably Palestinian. (Courtesy Ernesto Wolf Collection)

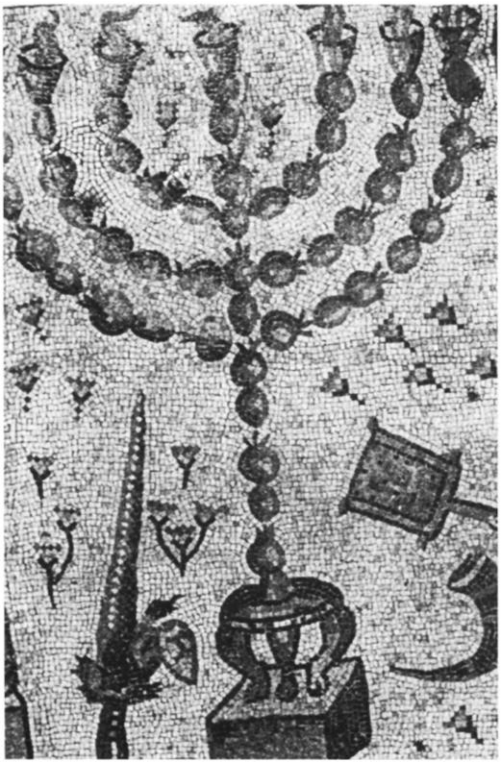

Fig. 29. Synagogue, Hammath Tiberias, mosaic showing menorah with burning glass lamps. Fourth century. (After Weinberg pl. 4:C)

could serve for individual suspension, and glass cones that could be mounted in holders (figs. 28, 29). A great technical improvement was the invention in the late fifth or early sixth century of the glass lamp with a built-in internal glass wick holder; this type of lamp was not common in the West.

Glass lamps were not widely used before the second half of the fourth century. By the end of the fifth century various shapes were common in most countries bordering the Mediterranean and Black Sea. They could be used architecturally for dramatic emphasis. The water collected and intensified the light of the flame so that the entire vessel glowed when it was lit.[250] In churches multiple lamps, set in metal fixtures known as polycandela, became a favorite type of illumination. According to the *Liber Pontificalis* (sixth century), Roman churches were illuminated with silver and gold *coronae* (polycandelae) suspended by chains as early as the pontificate of Silvester (314–335);[251] the lamps inserted in these polycandelae may have been made of precious metal or some material other than glass.[252] The earliest glass lamps excavated in Italy do not predate the late fourth/early fifth century.[253]

Forms and Function of Glass Vessels in the West

In the West, the second half of the first century was by far the most prolific period in terms of quantity, variety of forms, and variety of functions of glass vessels. This has been demonstrated for Britain and the European continent.[254] This may have also been true of the Pontic cities, but comparable data are not

[250] On lighting effects: C. Steckner, "Pharokantharoi und Kylikeia," *AnnAIHV* 11, 1988 (Amsterdam 1990) 257–70.

[251] H. Geertman, "L'illuminazione della basilica paleocristiana secondo il liber pontificalis," *RACrist* 64 (1988) 135–60.

[252] At Madinat az-Zahra, ceramic lamps were set in polycandela (10th century): F. Valdés Fernandez, "Kalifale Lampen," *MM* 25 (1984) 208–15, pl. 71.

[253] M. Uboldi, "Diffusione delle lampade vitree in età tardoantica e altomedievale e spunti per una tipologia," *Archeologia Medievale* 22 (1995) 93–145.

[254] Van Lith and Randsborg; Cool and Price 221–23.

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Table 2. Numbers of Vessel Forms from Colchester Grouped by Likely Function

Period (A.D.)	Drinking Vessels	Food Presentation Vessels	Liquid Serving Vessels	Storage Vessels	Storage Vessels for Liquid only	Other	Total Number of Forms
ca. 43–60/1	5	5	3	–	5	2	20
60/1–ca. 100	6	5	4	3	5	1	24
100–170	3	2	4	5	5	–	19
170–230	4	2	3	5	5	–	19
230–300	2	1	4	–	3	–	10
300–350	4	1	5	–	1	–	11
350–400+	4	2	4	–	1	1	12

After Cool and Price 223, table 13.1.

readily accessible for that area. In Palestine and Syria as well as Egypt, the floruit of blown vessel glass was the late Roman and early Byzantine periods (see below).

In the first century glass vessels were used in the West for a wide variety of purposes: as tablewares, for storage and transport of solids and liquids, for personal use (e.g., for cosmetics, scents, bath oils, and medicines), and various miscellaneous purposes. It is not clear why the functions served by glass declined sharply during the second to fourth centuries. By the fourth century almost all the glass made in the northwest provinces was tableware, in particular for drinking and serving liquids. An analysis of the glass excavated at Colchester (table 2) appears to reflect a pattern of use that was broadly similar across the western part of the Roman empire.[255]

Whereas the number of forms for jugs and flasks remained approximately unchanged from the second century on, showing a slight increase with respect to the variety available in the first century, there were fewer forms of drinking vessels to choose from, although there is no evidence to suggest that the actual number of drinking vessels decreased. On the other hand, the reduced choice in dishes for serving foods does seem to have been accompanied by a decrease in use of glass for this purpose.

Beginning in the third century the forms of glass storage vessels for solids and liquids became less varied. In the fourth century, the demand for variety in glass drinking vessels increased sharply. From then on drinking vessels were to remain the vessels with the largest variety in forms throughout Frankish and medieval times and drinking was to be the main function of glass vessels.[256]

Forms and Function of Glass Vessels in the East

The most prolific period of glass production in the eastern Mediterranean was the late Roman period. Egypt, Palestine, Syria, Cyprus, Asia Minor, and the north Pontic cities all had flourishing glass industries, and those of Syria and Palestine experienced a prolonged period of growth. Glassware played an increasingly important role in the daily life of all levels of society, to such an extent that in the fourth century glass vessels all but ousted pottery for certain functions.

With increased demand regionalism became a dominant factor in production. There are marked differences between the vessel glass made in Syria,[257] Jordan,[258] and Palestine, and also between different parts of Palestine: inland versus coast, western Galilee and southern Phoenicia versus Judea and areas

[255] On the functions of glasswares available in northwest Europe: van Lith and Randsborg passim. On the glass from Colchester: Cool and Price 211–36. Compare also: B. Rütti, *Vitudurum* 4: *Die Gläser* (Berichte der Zürcher Denkmalpflege Monographien 5, Zürich 1988) 109–23; Rütti 170–264; M.R. DeMaine, "The Northern Necropolis at Emona. Banquet Burials with Ladles," *AnnAIHV* 11, 1988 (Amsterdam 1990) 129–44; G. Sennequier, "Roman Glass Found in Upper Normandy," *JGS* 36 (1994) 56–66.

[256] L. Saguì, "Produzioni vetrarie a Roma tra tardo-antico e alto medioevo," in L. Paroli and P. Delogu eds., *La storia economica di Roma nell' alto medioevo alla luce dei recenti scavi archeologici* (Biblioteca di Archeologia Medievale, Firenze 1993) 113–36; Saguì, "Produzioni vetrarie a Roma tra V e VII secolo: nuovi dati archeologici," *AnnAIHV* 14, 1998 (forthcoming). E. Baumgartner and I. Krueger, *Phönix aus Sand und Asche: Glas des Mittelalters* (Munich 1988); Foy and Sennequier (supra n. 65); H.E. Henkes, *Glass without Gloss: Utility glass from five centuries excavated in the Low Countries 1300–1800* (Rotterdam Papers 9, Rotterdam 1994).

[257] C.W. Clairmont, *Excavations at Dura Europos. Final Report* 4, part 5: *The Glass Vessels* (New Haven 1963); S. Abdul Hak, "Contribution d'une découverte archéologique récente à l'étude de verrerie syrienne à l'époque romaine," *JGS* 7 (1965) 26–34. On the date of the tomb at Homs: Stern 1977 (supra n. 76) 83–84.

[258] O. Dussart, *Le verre en Jordanie et en Syrie du Sud* (Institut Français d'Archéologie du Proche-Orient, Bibliothèque archéologique et historique 152, Beirut 1998).

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farther south.[259] Remains of glassworking facilities have been identified at several sites in Israel; one furnace, active in the second half of the fourth century, has been excavated at Jalame.[260]

Palestine and southern Phoenicia were also major primary glass producers. Sixteen rectangular tank furnaces, dating from the first half of the seventh century, were excavated at Hadera, halfway between Tel Aviv and Haifa. Each furnace measured ca. 2 × 4 m and had a capacity of 8–10 tons per firing. The process took up to two weeks and the temperature in the furnaces reached ca. 1100°C. The furnaces appear to have functioned only for a short time, perhaps just one glassmaking season, until fuel supply in the vicinity was exhausted. Very little glass remained at the site, suggesting all of it was sold.[261]

The rise of the Severan dynasty (193–212) brought a higher level of prosperity to Syria.[262] Close connections with Rome benefited the native glass industry. Syrian glassworkers appear to have moved freely between East and West, with some artisans settling in the Rhineland. Certain types of luxury glass excavated in Cologne and Syria, such as glasses with snake-thread decoration[263] and flasks within flasks,[264] required technical know-how that was probably transmitted from craftsman to craftsman. The difficulties encountered by modern glassblowers attempting to duplicate these wares are an indication that such vessels could probably not be copied simply by studying a finished object. We may credit migrating glassblowers with the transfer of these specialized techniques.

The floruit of the Palestinian glass industry was the fourth to early fifth century. Following the rule of Diocletian (284–305), when civil strife plagued most of the western part of the empire, the eastern Mediterranean enjoyed an era of relative peace, despite economic instability. Palestine benefited from Constantine's decision after 324 to target the Holy Land for his building programs. Exempted from personal taxes by the imperial edict of 337, architects, painters, and sculptors, as well as selected categories of highly skilled craftsmen including glassworkers, profited greatly from the economic and cultural boom. Glassblowers created an abundance of new shapes and styles, many surviving into the Islamic period.

New types introduced in the late Roman period include: glass kohl tubes (fig. 30) widely used in Palestine,[265] jars (fig. 31) used in Palestine and Syria but with different styles, and sprinklers (fig. 32) used in Syria. Closely associated with cultural traditions of Syria and Palestine, these types remained largely unknown in the West. Also new in this period was the creation of specific glass vessel forms designed for interior lighting (see above). Lamps were destined to become one of the most important products of the Byzantine glass industry.

The forms and functions of vessel glass represented in assemblages from eastern Mediterranean sites have not yet been analyzed, but some general observations can be made, albeit with the reservation that the conclusions are preliminary and will need to be adjusted when detailed analyses of individual sites become available. With regard to the diversity of forms serving one function, the situation in Syria and Palestine developed opposite to the West.

A cursory count of common blown forms used in Palestine[266] serves only to indicate the trend (table 3). In the first and second centuries 13 forms of bowls and dishes were available for serving food, 4 forms of drinking vessels, and 3 forms for serving liquids, a total of 20 forms for the table. There were

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[259] D. Barag, *Hanita Tomb XV. A Tomb of the Third and Early Fourth Century CE* (Atiqot Engl. Ser. 13, Jerusalem 1978) 54–56; Gorin-Rosen (supra n. 208) 22–23.

[260] Weinberg; Stern 1992 (supra n. 44) 490–94.

[261] Y. Gorin-Rosen, "Hadera, Bet Eli'ezer," *Excavations and Surveys in Israel* 13 (1995) 42–43; Gorin-Rosen (supra n. 208) 17 with additional glassmaking sites, 14–17. A slab of raw glass from Beth Shearim was probably made in a similar installation: R.H. Brill, "A Great Glass Slab from Ancient Galilee," *Archaeology* 20 (1967) 88–95. I. Freestone has recently redated the slab to the ninth century, based on its chemical composition: I.C. Freestone and Y. Gorin-Rosen, "The Great Glass Slab at Bet She'arim, Israel: An Early Islamic Glassmaking Experiment?" *JGS* 41 (1999).

[262] Stern 1977 (supra n. 76) 155–58.

[263] On snake-thread decoration: Harden et al. (supra n. 16) 105–108 and nos. 55–67.

[264] D. Barag, "Syro-Palestinian Flasks within Flasks," *Atiqot Hebrew Series* 6 (1970) 74–75 [Hebrew], English summary p. 8*. On flasks within flasks made in Western European workshops: F. Fremersdorf, *Römische Gläser mit Fadenauflage in Köln* (Die Denkmäler des römischen Köln 5, Cologne 1959) pls. 76–79.

[265] On function, chronology, and typology of kohl tubes: Stern 1977 (supra n. 76); W.D. Blanchard et al., "Analysis of Materials contained in mid-4th to early 7th century A.D. Palestinian Kohl Tubes," in *Materials Issues in Art and Archaeology* 3 (Materials Research Society Symposium Proceedings 267, Pittsburgh 1992) 239–54; Stern (in prep.).

[266] Based on a rough count of individual forms depicted by D. Barag, *Glass Vessels of the Roman and Byzantine Periods in Palestine* (Diss. Hebrew University, Jerusalem 1970) 2: pls. 30–47; decorative variations within one shape are not counted, nor are forms not included in Barag's survey but known from excavated finds in Israel.

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Fig. 30. Kohl tube with two compartments. H. 12.85 cm; wt. 87.8 g. Pontil scar. Mid-fourth to mid-fifth century. Probably Palestinian. (Courtesy Toledo Museum of Art, no. 1923.1272. Gift of Edward Drummond Libbey.)

also 4 forms for storage and/or transportation, 37 forms of unguentaria, and 4 miscellaneous forms.

In the third to early fifth centuries about 30 individual forms were available for serving foods in bowls and dishes (not included are 20 Palestinian forms of jars that may or may not have been used as tablewares), 22 forms of cups and beakers, and 46 forms of jugs and flasks for serving liquids (i.e., a total of 98 forms of tablewares; 118, if the jars are included), 44 general purpose unguentaria (including 11 forms of kohl tubes), and 7 miscellaneous forms, including 1 form of spouted bottle and 2 forms of lamps. Glass was not common for bulk storage: perhaps four forms, probably less were available. These numbers do not include typical Syrian types such as sprinklers.[267]

Perhaps the most salient feature of the Byzantine period (fifth to early seventh centuries) is a tendency toward uniformity apparent throughout the empire. Certain types such as the ubiquitous stemmed goblet, also known as wineglass from its similarity to the modern wineglass, were used far beyond the borders of the empire. Likewise, the stemmed, footed flask enjoyed widespread distribution. Both types appear to have originated around the middle of the fifth century, presumably in Syria or Palestine. The functions of these types suggest that their popularity was

[267] On sprinklers: Stern 1977 (supra n. 76) 95–100; Stern 1995, 187 and nos. 129–33; Stern (in prep.).

Fig. 31. Jar. H. 7.7 cm; Weight 67.4 g. Pontil scar. Fourth century. Palestinian. (Courtesy Toledo Museum of Art, no. 1923.1032. Gift of Edward Drummond Libbey.)

due primarily to their use in churches, whether for drinking, as lighting apparatus, or both.

If the stemmed goblet was not the primary drinking vessel of the Byzantine period, one wonders what the ordinary cup looked like. In view of the large quantities of glass available it is not logical to hypothesize that vessels of other materials temporarily eclipsed glass drinking vessels. Drinking had been an important function of glass tablewares in the preceding centuries and was to be so again in the Islamic period; in the West drinking was the main function of glassware from the fifth century into modern times. I suggest that in the Byzantine empire goblets were not only used for lighting but also

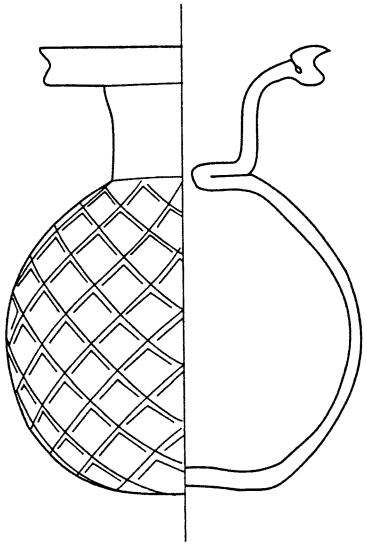

Fig. 32. Sprinkler. H. 6.9 cm; wt. 37.4 g. No pontil scar. First half of third century. Syrian. (Drawing courtesy of Toledo Museum of Art, after inv. no. 1923.1334. Gift of Edward Drummond Libbey.)

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Table 3. Numbers of Vessel Forms from Palestine Grouped by Likely Function

Vessel Forms	Period (cent. A.D.) 1st–2nd	3rd–Early 5th	5th–7th
Food Presentation			
Bowls, Jars, Dishes	13	50*	1
Drinking	4	22	9**
Pouring Jugs, Flasks	3	46	21
Storage Liquids	4	4	–
Storage Unguentaria	37	44	7
Lighting Lamps	–	2	17
Other	4	5	1
Total Tablewares	20	118*	31
Total All Forms	65	173	56
Total Functions	6	7	6**

* Includes 20 "jars."
** Includes 9 "wineglasses."

for drinking. In addition, it is conceivable that certain types of flasks doubled as drinking vessels.

In Palestine, the three most common functions reserved for glass vessels in the Byzantine period include pouring (21 forms, 18 of which were flasks without handles), lighting (17 forms of glass lamps, not including 5 forms of wineglass that were probably used for drinking as well as lighting), and one local type of cosmetics container, the Palestinian kohl tube for which a minimum of seven individual forms were available. Glass bowls and dishes probably remained in use but they are not easily recognizable among the common blown Palestinian forms of the period. To judge from the glass excavated at Sardis, the same may have held true in other parts of the Byzantine empire. Classical Roman types such as the footed wine-jug with trefoil mouth, shallow and deep bowls for serving foods, as well as flat-bottomed cups and beakers for drinking had become obsolete.

CONCLUSIONS

Philological, archaeological, and technical evidence shows that crucial improvements in glassblowing, now taken for granted, occurred in Italy over time during the first century. Physical restrictions imposed by size and construction of the Roman glass furnace limited the number of glassblowers who could work in one shop, setting glassblowing apart from other fire-based crafts such as pottery and metalsmithing. Almost every glassblower depended on the smooth functioning of long distance trade since the raw glass needed for blowing was made at only a few sites. An analysis of the maximum prices for glass quoted in the PE shows that the glassblower who specialized in vessel production would have had great difficulties in making a profit. A separate section on glass mosaic cubes may have been included in PE 16.7–9.

Due to their unique association with Roman culture, blown glass tableware played an important role in bringing Roman culture to the new provinces in Europe. Glass was an important item of trade beyond the frontier. Trade with Africa and India was brisk. Glass vessels were objects of daily use in most segments of society but their function and the numbers of forms available differed considerably in West and East. Whereas in the West the diversity of functions and individual forms was by far the greatest in the first century, with a marked decline in diversity beginning at the end of the second century, the diversity of individual forms in use in Syria and Palestine reached its peak in the fourth and early fifth century and was unrivalled in any other period of history.

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